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White Sands Missile Range 2007 Urban Study: Data Processing – Volume DP-2 (Main Dataset)

by Gail Vaucher, Sean D'Arcy, Robert Brice, Manuel Bustillos, and Ron Cionco

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14. ABSTRACT

This report (Volume DP-2) completes the initial series of *White Sands Missile Range 2007 Urban Study* (*W07US*) documentation. The term "data processing" can generate a wide variety of expectations across the many scientific disciplines. For *W07US*, data processing included all actions leading to the most informative quality data output relevant to the mission objectives. Thus, the data processing task began with the inception of the field study, continued through the extensive data acquisition period, and persisted through this Post-*W07US* data evaluation effort. This report focuses on the three key areas of the Post-*W07US* main dataset data processing effort: the data survey, the data averaging, and the data trends. After examining the dynamic and thermodynamic main datasets, we believe that the quality of data acquired has the potential to enrich many different types of urban research projects.

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Summary

This report (Volume DP-2) completes the initial series of *White Sands Missile Range (WSMR) 2007 Urban Study* (*W07US*) documentation. At the time of this writing the *W07US* series consisted of an overview of the *W07US* field study preparation and execution information (ARL-TR-4255, Volume 1), the calibration data processing and results (ARL-TR-4439, Volume DP-1), the main dataset data processing and results (ARL-TR-4440, Volume DP-2; this report), the data processing airflow qualitative assessment (ARL-TR-4441, Volume DP-3), and the data processing atmospheric stability qualitative assessment (ARL-TR-4452, Volume AS-2)[*].

The term "data processing" can generate a wide variety of expectations across the many scientific disciplines. For *W07US*, data processing included all actions leading to the most informative quality data output relevant to the mission objectives. Thus, the data processing task began with the inception of the field study, continued through the extensive data acquisition period, and persisted through this Post-*W07US* data evaluation effort.

This report focuses on the three key areas of the Post-*W07US* main dataset data processing effort: the data survey, the data averaging, and the data trends. The data survey divided the 32 GB of main dataset data into two categories: the dynamic data and the thermodynamic data. These categories were distinguished by their data acquisition system (DAS). Missing data from each category were tabulated as a function of causes. For the dynamic data, six causes were identified to explain the less than 2% of missing data. The single occurrence of missing thermodynamic data was declared insignificant (less than 0.01%; only 2 min were missing!).

The data averaging efforts required an evaluation of the data time stamps. The time stamp for the dynamic data utilized a non-internal source. Consequently, there were occasional data alignments with nonlinear time stamps. Using the philosophy that all data are valued, these "added" data were preserved and subjected to a time synchronization routine when averaged. The time stamp for the thermodynamic DAS was internal and therefore experienced only linear time stamping.

The data trends explored both the horizontal and vertical attributes of the overall main dataset. With such a massive amount of data over a relatively short spatial area, the decision was made to utilize the targeted airflow features as dynamic data reference points for the larger dataset. This method was equivalent to the astronomer's technique of using stars and star clusters to map the heavens. All seven primary flow features were statistically assessed for their frequency of

[*]Note: ARL-TR-4256, Volume AS-1, describes the urban-small building complex environment by comparing stable patterns from two similar urban field studies. These two field studies were *WSMR 2003 Urban Study* (*W03US*) and *WSMR 2005 Urban Study* (*W05US*).

occurrence, as a function of a sampling day. All airflow features were present on each day of the *W07US* data acquisition period. This initial qualitative assessment defined each feature in its ideal form. Several suggestions for future urban airflow investigations were identified in the form of observations and recommendations.

The thermodynamic data trends were examined through spatial and temporal perspectives. With an underlying goal of defining and being able to predict an urban diurnal stability cycle, the data trend investigation focused on the unusual urban character of a stable atmosphere around a building. The results from the earlier two field studies conducted at the same test site and during the same calendar month as *W07US* were weighed into the assessment. This added information provided the needed contrast for extracting the stability patterns. Eight urban, single building, stable environment characteristics were identified. These included the following:

Spatial Characteristics

1. During windy conditions, stable environments favored the building leeside.
2. During non-windy conditions, stable environments favored the building windward (Fetch) side.
3. The roof with a heating vent generated a stable environment.

Temporal Characteristics

4. The most populated period for stable environment occurrence was midnight ±3 h.
5. Second most populated period for stable environment occurrence was sunrise ±3 h.
6. The average duration of consecutive minutes for stable conditions was 6–8 min.
7. The extreme durations for consecutive stable minutes ranged from 14–312 min.
8. Extreme stable case durations favored the non-windy environments.

Quality data was the goal for the *W07US* data processing efforts. After examining both the dynamic and thermodynamic datasets, we believe that the quality of data acquired has the potential to enrich many different types of urban research projects.

1. Introduction

Toxic chemical and biological releases in an urban environment are a very real threat to the civilian and military alike. The U.S. Army Research Laboratory (ARL) has been strengthening their understanding of the atmospheric urban environment through a series of urban field studies conducted at White Sands Missile Range (WSMR), NM.

In March 2007, ARL conducted the third of three progressively more complex urban studies investigating the airflow and stability characteristics around and above a single urban building. The field portion of this research was entitled *WSMR 2007 Urban Study* (*W07US*). *W07US* involved two data acquisition systems (DASs), 51 sensors and 12 towers/tripods strategically placed to optimize the airflow and stability investigation. Fifty-two gigabytes of informative data were generated. The subsequent processing of this dataset has been the topic of several technical reports already published. An overview of the *W07US* preparation, execution, and preliminary findings was documented in ARL-TR-4255 (Volume 1). This initial report also included the early (planning) stages of the data processing effort. Four subsequent reports document the post-field portion efforts to process and analyze the data:

- The data processing (DP) of the Pre- and Post-*W07US* calibration data was presented in ARL-TR-4439 (Volume DP-1).
- This report, Volume DP-2, documents key features of the main dataset that were extracted during the main dataset data processing.
- ARL-TR-4441 (Volume DP-3) and ARL-TR-4452 (Volume AS-2) document the airflow and atmospheric stability (AS) qualitative assessments, respectively.

Due to time-constraints, much of these post-*W07US* data processing efforts were conducted concurrently; therefore, their publication dates could not be sequential. We have, however, made every effort to integrate the available findings whenever possible.

The six mission objectives defining *W07US* consisted of scientific, technical, and research application topics. The specific objectives were as follows:

Scientific Goals

1. To acquire data for verification of urban models, such as the Three-Dimensional Wind Field (3DWF) model.
2. To characterize behavior of turbulent airflow around and above a single building.
3. To characterize surface layer stability patterns in an urban environment.

Technological Goals

1. To design, develop, test, and evaluate integrated DAS hardware/software.
2. To evaluate sensor systems for Safari unit design.

Applications

1. To demonstrate disaster response applications as applicable to a single office building.

In section 1.1, the data processing concept is introduced. Section 1.2 describes the *W07US* data processing plan in the context of the four-phased *W07US Test Plan* (Vaucher, 2006) and Project.

1.1 Data Processing

Data processing for a scientific field project is initiated at the inception of a field study and continues throughout the field study execution and on into the Post-*Study* activities. The ultimate goal of the data processing is to ensure a quality dataset. Often, lessons learned will stem from the data processing efforts and, when documented, are invaluable contributors toward improving future field studies.

1.2 *W07US* Data Processing Plan

The *W07US* project was divided into four-phases:

- 2006 July–07 Mar.: *W07US* Preparation
- 2007 Feb./Mar.: Pre-*W07US* Calibration
- 2007 Mar./Apr.: *W07US* Field Portion
- 2007 Apr./May: Post-*W07US* Calibration, Preliminary Summary, and Data Analysis

The data processing plan was an integral part of the *W07US* project and began during the *W07US* Preparation phase. Once the objectives were defined, the requirement for 51 sensors to sample data 24 h per day, 7 days per week, over an uninterrupted 2-week period was subsequently ascertained. This requirement included 26 sensors collecting thermodynamic data and 25 sensors collecting dynamic data. The thermodynamic data output was defined as 1-min time averages. The dynamic data output was chosen to be 20 Hz samples. To help ensure the best opportunity for top data quality, the data processing plan called for all sensors to be calibrated before and after the actual field execution.

There are many known hazards associated with acquiring a very large dataset over a short time period; therefore, the data processing plan required each sensor to be evaluated for functionality before, during, and after the field study. The Pre- and Post-*W07US* Calibration of each sensor satisfied the "before" and "after" requirements. The "during" *W07US* requirement was carried out through a daily monitoring of all sensors. This monitoring effort included downloading data from all 51 sensors, calculating 1-min averages, plotting/printing each variable's time series, and

reviewing the output for system, software, and/or instrument failures. The monitoring implementation utilized four trained professionals, working in tandem, to review over 388,000,000 datum points (approximately 1 day's worth of data) over a 4–5 h time period during each day of the *W07US* Field Portion.

After the *W07US* Field Portion was completed, a three-step Post-*W07US* data processing plan was put into action. These steps included (1) processing the *W07US* calibration data, (2) processing the main dataset with a focus on the overall quality of the acquired data, and (3) processing the main dataset with a focus on the data quality with respect to the intended scientific objectives. As explained earlier, time constraints revised the sequential three-part plan into a concurrent tasking. Consequently, the reports documenting the results were published non-sequentially. For information regarding step 1, the processing of the *W07US* calibration data, see ARL-TR-4439 (Volume DP-1). For the overall quality of the main dataset, or step 2, refer to this data processing technical report ARL-TR-4440 (Volume DP-2). For step 3 information, the data quality with respect to the scientific objectives, see ARL-TR-4441 (Volume DP-3) and ARL-TR-4452 (Volume AS-2).

2. *W07US* Data Processing ("Step 2")

Step 2 of the *W07US* data processing plan focused on the quality of the main dataset. A total of 52 GB of data had been collected; 32 GB of these data composed the main dataset being evaluated. The three key data attributes investigated were (1) the data survey, (2) the data trends, and (3) the data averaging. Each will be addressed in the subsequent subsections.

2.1 Data Survey

The first data attribute investigated evaluated the data source, namely, the sensor functionality and sensor selection. Based on the Pre- and Post-*W07US* calibration and daily monitoring of sensor results, all sensors were determined to be functioning correctly[†].

Next, the data survey subdivided the large main dataset into two categories: the dynamic and the thermodynamic data. Each category was further defined by its independent DAS. For example, the dynamic data were sampled by the RM Young ultrasonic anemometers (sonics) Model 81000 and linked together via a wireless DAS designed and constructed specifically for *W07US*. The thermodynamic data consisted of a variety of sensors linked together via the Campbell CR23X micro-loggers. The micro-logger data were downloaded onto a thumb drive and sneaker-netted to a dedicated Excel spreadsheet for processing. Each of the resulting two datasets will be described separately in the following sections.

[†]The purpose of this report is to document the main dataset characteristics; therefore, a discussion on the calibration and calibration results will not be included. For additional information on the calibration efforts, see ARL-TR-4439 (Volume DP-1).

2.1.1 Dynamic Dataset Notation and Missing Data

The dynamic data resources were composed of 27 sonics: 25 fielded sonics, 1 backup sonic, and 1 calibration standard. The raw *W07US* data were sampled at 20 Hz. Data files were subdivided by day (a 24 h period, from midnight to midnight) and stored in hourly segments (0–59.99 min). The distribution of the sonics, as a function of above ground level (AGL) mounting height, is summarized in table 1.

Table 1. Distribution of sonics used in *W07US*.

Sonic Location (AGL)	*Number of Sonics*
10m	5
6m	1
5m	6
2.5m	13
Total sonics used	25

The data files were labeled according to the location within the field site design. The location notation consisted of the mounting structure and the level on which the sonic was mounted. There were 12 unique field site structures, each designated by a sequential number and a two-letter label. These letter labels signified a compass location with respect to the field study's subject building. For example, the tower north of the subject building was labeled "NN." The tower to the southwest of the subject building was labeled "SW." Figure 1 provides a schematic of the *W07US* test site layout. Appendix A expands on this same layout by showing a vertical schematic of the *W07US* test site layout, along with a series of top-down schematics that have photographic images linked with each tower and tripod structure. Table 2 correlates the reference numbers with the tower compass label, sensor level, and sonic number.

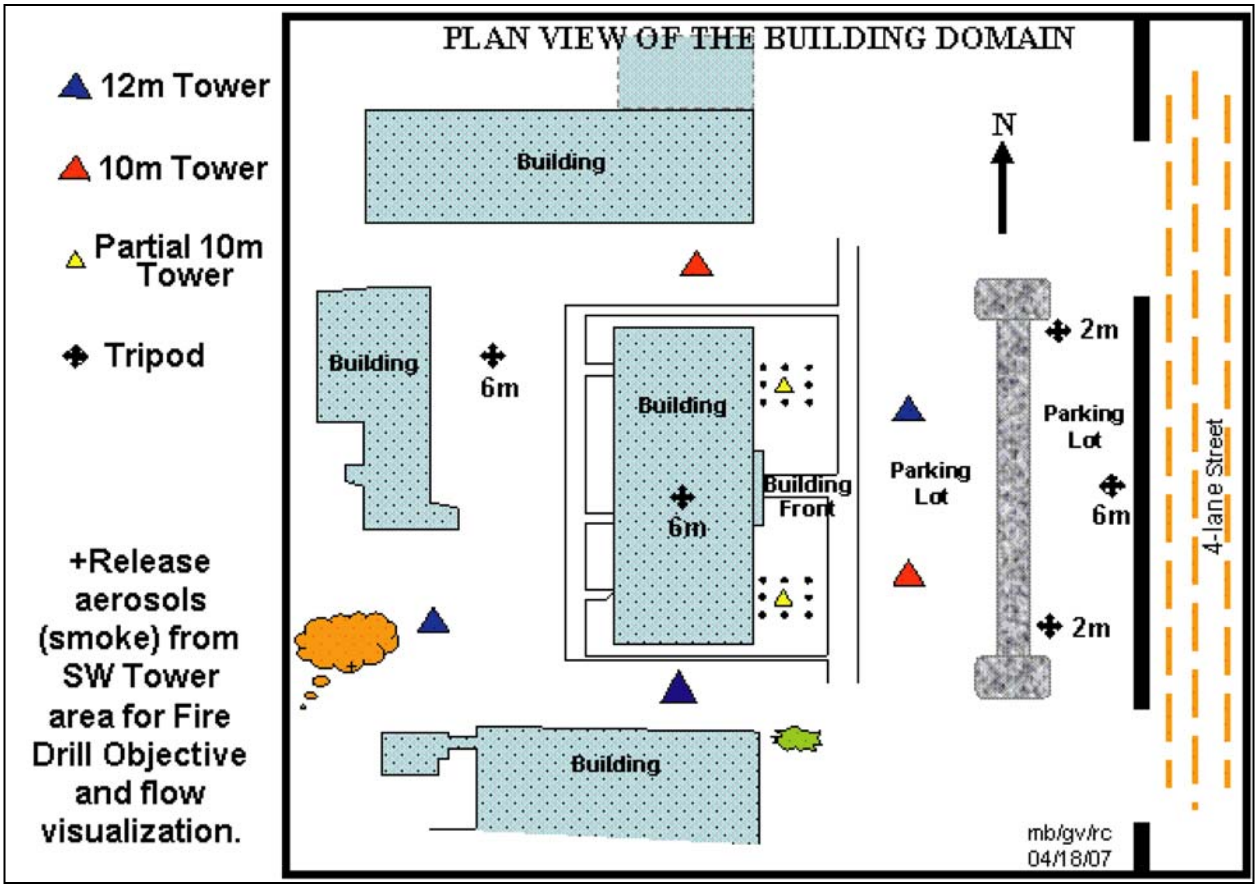

Figure 1. Schematic of *W07US* test site layout.

Note: The black dots surrounding the partial 10 m towers are fence posts with telltale flags. The term "partial tower" means that the tower included only two of the three vertical telescoping sections.

All sonics were mounted on the west side of the towers and tripods. Partial towers Vortex-South (VS) and Vortex-North (VN), however, supported booms at the same height on both the west and east sides of the structure. The side on which the individual VS and VN sonics were mounted is notated in table 2 under the "Tower/Tripod" and the "Sonic Number." The latter uses one-letter shorthand: west (w) and east (e). Where only four characters were available for the sonic numbering code, the initial "1" was dropped to make room for the "w" or "e" notation at the end of the number. The same was true for the Reattachment East tripod 2.5 m level and the Northwest tripod 2.5 m level.

Table 2. *W07US* main dataset sonic labeling references.

Reference Number	Tower or Tripod Structure	Level AGL (m)	Sonic Number
01	Southwest (SW)	10	1360
01	SW	5	1358
01	SW	2.5	1359
02	South (S)	10	1330
02	S	5	1338
02	S	2.5	1342
03	Northeast (NE)	10	1357
03	NE	5	1356
03	NE	2.5	1355
04	North (NN)	10	1354
04	NN	2.5	1353
05	Roof (RR)	6	1374
06	Southeast (SE)	10	1362
06	SE	2.5	1361
07	Reattachment-South (RS)	2.5	1377
08	Reattachment-East (RE)	5	1376
08	RE	2.5	1375
09	Reattachment-North (RN)	2.5	1373
10	Vortex-South (VS) – west	5	1370w
10	VS – west	2.5	1369w
10	VS – east	2.5	1368e
11	Vortex-North (VN) –west	2.5	1372w
11	VN – east	2.5	1371e
12	Northwest (NW)	5	0637
12	NW	2.5	0638

Originally, this report included a section explaining the file notation systems for both raw and processed data files. To help minimize confusion, this information has been reduced to just the file notation used for the *W07US* data that is anticipated as being made available to other urban atmospheric researchers. The *W07US* data file names follow this pattern:

- Reference number_
- Two letter tower code_
- Sonic number_
- Sonic heightm_
- Date of data collection in the format of YYYYMMDD_
- Starting hour in local time for data in file
- .
- Text (txt)

So that, a sonic data file named "01_SW_1360_05m_20070325_0000.txt" would mean that the data in the file was acquired from the following:

- Reference number 1
- Southwest tower
- Sonic number 1360
- Sonic height was 5 m (in default location: west of the tower structure)
- Data was collected on 2007 March 25
- This file's data started at 0000 local time (LT) and extends one hour (0–59.999983 min only)
- .
- This is a text file.

A review of the dynamic (sonic) data-file notation, along with the dynamic data file format, is located in appendix B.

Continuing with the sonic data survey, for efficiency, the data being evaluated were processed into 1-min averages. Based on the time-aligned 1-min average files, a survey of missing data was conducted. Table 3 summarizes the results. A more detailed list of sonic locations is provided in appendix C.

Table 3. Dynamic data: Missing data survey.

Tower Code	Sonic Number	Total Minutes Missing	Total Minutes Present
SW	1360	3	20157
SW	1358	3	20157
SW	1359	3	20157
SS	1330	1496	18664
SS	1338	1496	18664
SS	1342	1496	18664
NE	1357	1	20159
NE	1356	1	20159
NE	1355	1	20159
NN	1354	59	20101
NN	1353	59	20101
RR	1374	582	19578
SE	1362	26	20134
SE	1361	1	20159
RS	1377	1	20159
RE	1376	1	20159
RE	1375	1	20159
RN	1373	1	20159
VS	1370	1	20159
VS	1369w	1	20159
VS	1368e	1	20159
VN	1372w	1	20159
VN	1371e	1	20159
NW	0637	1411	18749
NW	0638	1412	18748

The total number of minutes sampled by the sonics was 495,941 min (or 8265.68 h). The percentage of missing minutes was 1.6% of this total sonic main dataset. Each missing data event was evaluated and a cause was ascertained. Table 4 lists the six causes identified, along with the number of occurrences and the towers/sonics impacted.

Table 4. Dynamic data: Missing data causes, events, and sensors impacted.

Missing Data Cause	Number of Missing Data Events	Tower Location and Number of Sonics Impacted
Planned maintenance	21	SW3, SS3, NE3, RR1, SE2, RS1, RE2, RN1, VS3, VN2
Excessive error flags	17	SE1
System universal serial bus (USB) outages	5	SS3, NW2
System USB reset	4	NW2
Power loss	4	SW3, RR1
Emergency maintenance	2	NN2

The cause for the greatest number of missing data events was a "planned maintenance" that impacted all the functioning sonics on Julian Day number 79. This field wide interruption lasted only 1 min and was, therefore, not a concern. In contrast, during this same time period, the North tower required an emergency maintenance, which generated a 59 min interruption in the NN data file. Once the NN tower was brought back online, there were no further interruptions in the data acquisition.

The second greatest cause for missing data was "excessive error flags," which occurred only in the data file generated by sonic number 1362 (SE-10 m). The majority of these flags were reported on Julian Day numbers 79 and 80. This initial interruption removed 26 min of data over the two-day period. On Julian Day numbers 84, 85, and 86, a similar interruption occurred but only involved one minute's worth of data per day.

The system USB outages, a need to reset a USB, and a power loss occurred 5, 4, and 4 times, respectively, during the main dataset acquisition. When these events occurred during non-work hours, the magnitude of missing minutes was proportionally large. Such was the case for the South tower, as well as the Roof and Northwest tripods (see table 3).

Balancing these numbers against the heavy demands of a 24/7, 20 Hz data acquisition, the fact that the total missing data was less than 2% of the entire main dataset was most encouraging.

2.1.2 Thermodynamic Dataset Notation and Missing Data

The thermodynamic data were acquired using 5 Campbell CR23X micro-loggers mounted on separate tower/tripod structures, supporting a total of 26 meteorological sensors. The 26 sensors quantified 7 variables, including pressure, temperature, relative humidity, wind speed, wind direction, solar radiation, and net solar radiation. All but temperature were sampled at a single level on the tower/tripod structures. Temperature was sampled at two levels in order to establish a stability assessment for each location. The sensors used to acquire the variables are listed in table 5. The thermodynamic sensors were mounted on the east or south side of the tower/tripod structure. Note: Some sensors collect more than one variable. For example, the HMP45AC sensor collected both temperature and humidity; the wind monitor collected both wind speed and wind direction.

Table 5. Thermodynamic data: Sensors, variables, and units.

Variable	Sensor	Manufacturer	Model	Units
Pressure	Barometer	Vaisala	PTB-101B	Millibars (mb)
Temperature	Thermometer	Campbell	T107	Celsius
Temperature/ relative humidity	Thermometer / hygrometer	Vaisala	HMP45AC	Celsius/percent
Wind speed and direction	Wind monitor	RM Young	05103	Meters/second, and degrees
Solar radiation	Pyranometer	Kipp/Zonen	CM3	Watts/meter^2
Net solar radiation	Net radiometer	Kipp/Zonen[a]	NR-LITE	Watts/meter^2

[a]This was misprinted in the original Volume 1 table.

The data variables acquired by tower/tripod are identified in table 6. A color coding by tower is used to help correlative tower information with subsequent tables. Table 6 is purposefully listed with the micro-logger number in chronological order. Future tables will list the towers/tripod in a counterclockwise path around the subject building. This latter ordering of structures is based on the stability research interests. Note: The tower references use the same two letter compass reference code as the dynamic dataset.

Table 6. Thermodynamic data: Variables versus micro-loggers.

Tower	Micro-logger Number	Pressure Sensors	Temperature Sensors	Relative Humidity Sensors	Wind Speed/ Direction Sensors	Solar Radiation Sensors	Net Solar Radiation Sensors
RR	3405		2		1		1
NN	4607	1	2	1	1	1	
SS	4647	1	2	1	1	1	1
NE	4649	1	2	1	1	1	
SW	4650	1	2	1	1	1	1

Data were acquired approximately every 10 s, then a 1-min average was calculated and stored in the micro-logger. These data were then downloaded onto a storage medium for the daily monitoring/processing. The acquisition system was designed for a continuous data feed; thus, there were no significant system-induced interruptions in the thermodynamic data. The only 2-min gap reported occurred in the Southwest tower dataset on Julian Day 82 and was due to human error made while downloading data. All other towers reported no missing data. The total number of minutes continuously acquired by tower ranged from 25,809 to 25,863. The slight variation in total minutes of data collection reflects the sequence in which the thermodynamic systems were initiated and terminated.

Table 7 summarizes the thermodynamic data surveyed. The total number of days for the thermodynamic data differs from the dynamic data due to the shorter time needed to mount and declare the thermodynamic field data acceptable for research. Aside: The time needed for the Pre-*W07US* sonic calibration data evaluation did not interfere with the planned *W07US* start date, which occurred right on schedule.

Table 7. Thermodynamic data: Total minutes of data acquired.

Reference Number	Tower	Micro-logger Number	Total Minutes of Acquired Data	Total Hours of Acquired Data
01	SW	4650	25809	430.15
02	SS	4647	25829	430.48
03	NE	4649	25847	430.78
04	NN	4607	25863	431.05
05	RR	3405	25860	431.00

As with the dynamic dataset, the description of the thermodynamic file notation will focus on the data that are anticipated as being made available to other urban atmospheric researchers. At the time of this writing, the thermodynamic data were organized into two presentations: a continuous stream of data by tower and a set of daily data files by tower. Both the continuous stream of data and the daily data files begin at the official start of the field study, 2007 March 19 (midnight), and end at the official field study conclusion, 2007 April 1 (midnight). The only difference is the file content: The "continuous" files contain no break in between the start and end points; the "daily" files contain only a midnight to midnight period of the data. The two data endpoints were chosen to align the thermodynamic data with the dynamic data.

The raw *W07US* thermodynamic data file names follow this pattern:

- Micro-logger number_
- Tower code_
- Date of data collection in the format of YYMMDD
- .
- Text (txt)

So that file "4650_SW2_070319.txt" means that the data in this file came from micro-logger number 4650, which was mounted on the Southwest tower, and contains data from 2007 March 19 (00:00 to 23:59 LT). Note: The added "2" indicates that there were two types of solar radiation sensors used on this tower. The default (without a "2") indicates only one solar radiation sensor was utilized.

A review of the thermodynamic data-file notation, along with the various data file formats, is located in appendix D.

2.2 Data Averaging

The dynamic data averaging began as a function of the individual files. This method provided a very efficient, daily, data processing effort for evaluating sensor functionality during the field execution. For the Post-*W07US* dynamic data processing, which involved far more inter-sensor comparison analyses, the incongruity of time stamps made the Post-*W07US* data processing impossible. Thus, the data averaging method was revised into time-aligned averages and will be explained in the subsequent section.

2.2.1 Time Synchronization and Time Stamp Alignments

The Post-*W07US* dynamic data processing averages were calculated over a time period evenly divisible into 1 h, such as 1-min averages. All data between the start and end of each time period were averaged, and the midpoint of that time period was assigned as the averaged data's time stamp. All time stamps were recorded in decimal hours (dec hr) from midnight. For example,

the first average of the 0600 h file would be 06.000000 to 06.016667 dec hr. The time stamp for this averaged minute would be 06.008333 dec hr. In the format of "hours:minutes:seconds", the first average of the 0600 h file would be: 6:00:00 to 6:01:00; and, the averaged minute would be time stamped at 6:00:30. This process ensured that time stamps for each sensor were synchronous. (Vaucher et al., 2008)

As an added confidence builder, the time synchronized averaging routine was independently validated using a technique described in ARL-TR-4439 (Volume DP-1) (Vaucher et al., 2008). Though the validation was implemented on the calibration data (the first processed data), the same averaging scheme was used for the dynamic main dataset.

2.2.2 Duplicate Time Stamp Cases and their Resolutions

Time stamps were applied to each sonic sample as it was written to disk. The time stamp was based on the system clock. System clocks for each data acquisition system were synchronized with a central server using Network Time Protocol (NTP). During the occasional network interruption, the system time for an individual system could drift from the central server. If this drift was more than a few seconds, the NTP client would reset the system time to synchronize with the central server upon reestablishment of network connectivity. This action resulted in discontinuities in the time stamps, with time stamp values jumping forward or backward. These discontinuities occurred rarely, and the largest offsets were less than 30 s. In the case of the time stamp values jumping backward, time stamps would overlap for a short period of time. When calculating averages for these time periods, the "extra" overlapping data were included in the next average period computed. (Vaucher, 2007a)

2.3 Data Trends

The first trend noted originated from an empirical observation made during the execution of the field study. The major wind events anticipated by the regional climatological data and from observations made during the earlier two field studies executed at the same site during the same month did not occur. To quantify this empirical observation, 1-min averages were calculated from the Southwest tower's dynamic data. This tower was chosen based on its function as the *W07US* "Fetch tower." By definition, the Fetch tower was the tower strategically positioned for characterizing the airflow prior to its interactions with the subject building. The optimal *W07US*-Fetch airflow called for vertical consistency; therefore, all three levels of data acquired (2.5, 5, and 10 m AGL) were required to show the same character. Histograms of the qualifying Fetch wind speeds and directions were constructed.

Figure 2 shows the vertically consistent wind speeds as a function of the Beaufort Wind Scale (Wikipedia, 2008a). About 56% of a *W07US* sampling day qualified with vertically consistent velocities. Within these qualifying data, the dominant airflow velocity (38%) was the "Light Air" (0.5–2.1 m/s). The second most frequent (8.5%) vertically consistent velocity recorded was

"Light Breeze" (2.1–3.6 m/s). The strongest, vertically consistent velocity occurred on Julian Day 82, was called "Fresh Breeze" (8.7–11.3 m/s) and lasted only 0.03% of that day.

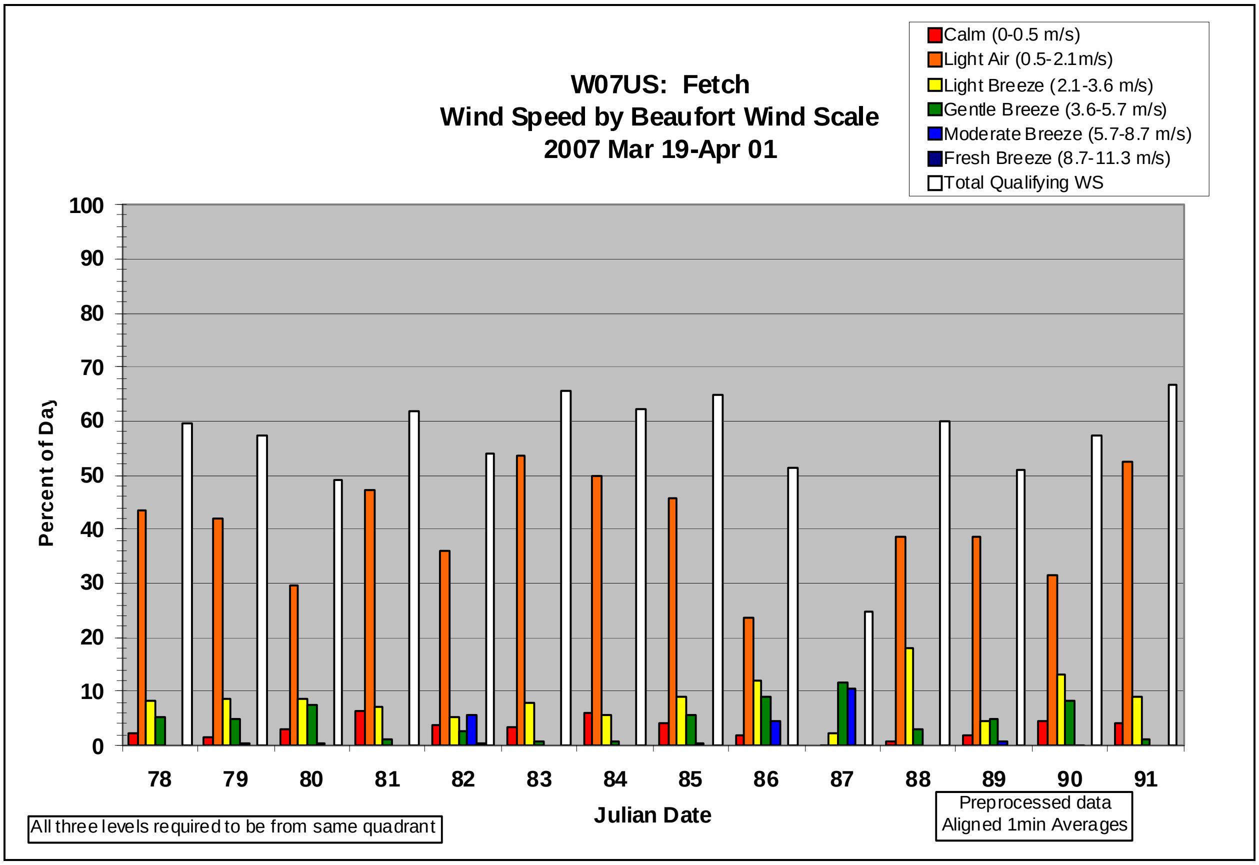

Figure 2. *W07US* Data Trends: Vertically consistent wind speeds as a function of the Beaufort Wind Scale.

In figure 3, a histogram of the vertically consistent wind directions is presented. The four basic compass quadrants were used to evaluate the wind directions. The vertically consistent wind directions from the Fetch tower averaged about 84% of a sampling day (indicating that inconsistent wind direction scenarios were present for ~16% of the day sample). The dominant direction was from the west (44%). Both northerly and southerly winds occurred about 16% of the time. And, the least frequent, vertically consistent wind direction was easterly (8.5%).

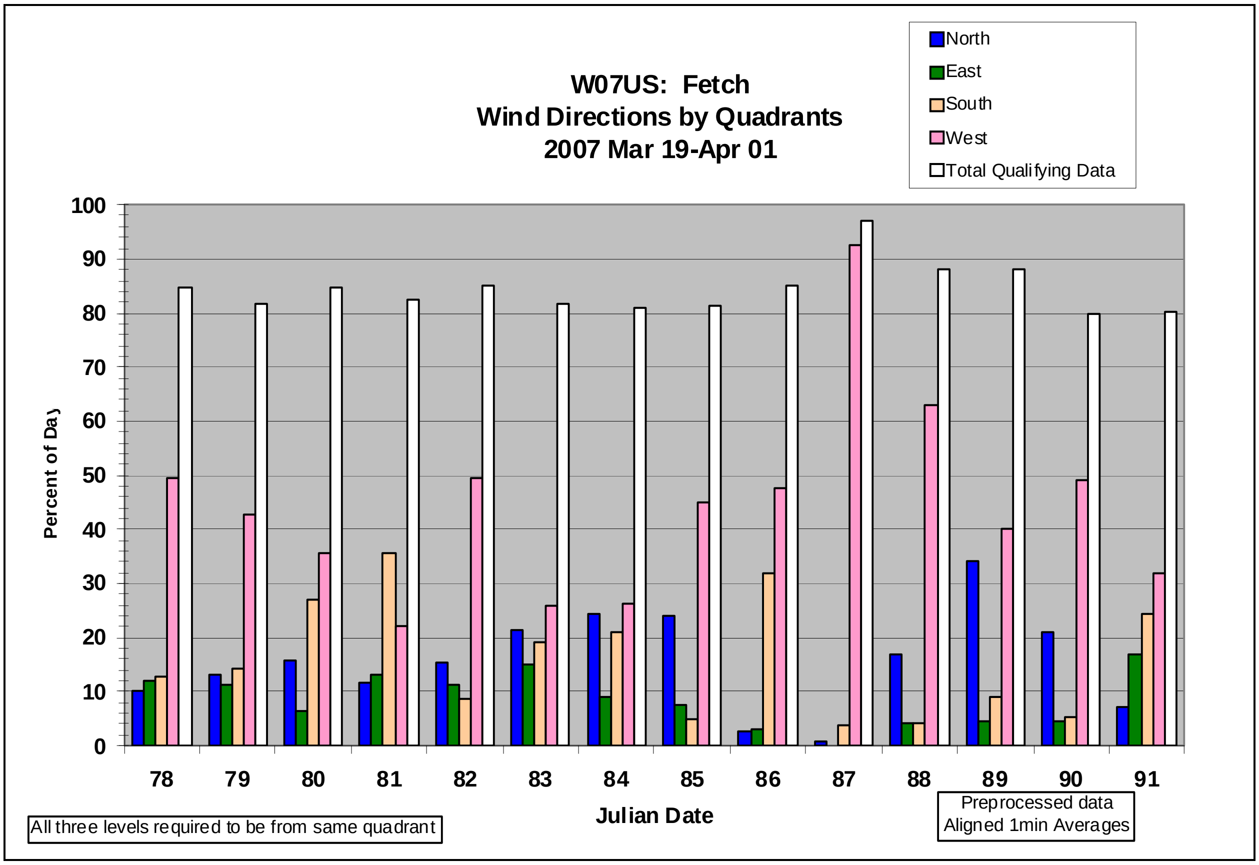

Figure 3. *W07US* Data Trends: Vertically consistent wind directions as a function of compass quadrants.

Assimilating the above findings, the empirical observation that strong wind events were not frequent in occurrence was validated. In fact, the dominant *W07US* airflow was westerly at "Light Air" velocities.

2.3.1 Airflow Qualitative Assessment Results and Recommendations

Despite the limited periods of consistently strong winds during *W07US*, all seven of the airflow features targeted for validation within the *W07US Test Plan* were observed on each day of the field study. Using time-aligned 1-min averages for each sonic, the airflow features were qualitatively assessed. This assessment utilized both horizontal and vertical perspectives within the dataset. What follows is a summary of the airflow qualitative assessment results. For a more in depth discussion on this topic, see ARL-TR-4441 (Vaucher et al., 2008).

The seven airflow features targeted for validation during *W07US* included Fetch Flow, Velocity Acceleration, Velocity Deficit, Cavity Flow, Canyon Flow, Leeside Corner Eddies, and Reattachment Zone (RAZ). For more information on these features, see Snyder and Lawson (1994). When conducting the airflow qualitative assessment, each feature was defined as a type of reference point on the multi-dimensional *W07US* main dataset map, just as an astronomer would use the stars and star clusters to map the vast heavens.

Each feature was initially examined independent of the other features, and under the most fundamental ideal conditions. For some features, such as the Cavity Flow and Leeside Corner Eddies, both the vertical and horizontal aspects of the feature were investigated. Other features, such as the Velocity Acceleration/Deficit (VAD) and Canyon Flows, required an extended horizontal perspective. All features were statistically tabulated for their frequency of occurrence, as scaled by a sampling day. The results are summarized in table 8.

Table 8. Statistical summary of the *W07US* airflow features (Vaucher et al., 2008).

Airflow Features	Frequency of Occurrence/Day
Velocity Acceleration	NE: 33% SE: 38%
Velocity Deficit	NE: 33% SE: 38%
Cavity Flow-Northeast	NE: 4(±3)%
Cavity Flow-Southeast	SE: 8(±6)%
Reattachment Zone-North	N: 39(±14)%
Reattachment Zone-East	E: 11(±3)%
Reattachment Zone-South	S: 26(±11)%
Canyon Flow-North	N: 21(±12)%
Canyon Flow-South	S: 18(±12)%
Canyon Flow-West	NW: 42(±15)%
Leeside Corner Eddy-Northeast	NE: 3(±-1)%
Leeside Corner Eddy-Southeast	SE: 3(±1)%
	All flow patterns were observed.

Note: E = east, N = north, NE = northeast, NW= northwest, S = south, SE = southeast, and W = west.

As mentioned earlier, all features were verified as present in their ideal form during some portion of each day sampled. Sample cases within the time series data were extracted for further airflow feature verification. While the assessment statistics provided the confidence that each feature was indeed present daily, the individual time series cases analyzed provided a more intimate airflow feature characterization.

The relatively low frequency of occurrence for the building leeside features were a function of the atypical climatological wind conditions provided during the data acquisition period, as well as local morphology. The slower-than-expected airflow velocities on the subject building's windward side, translated into fewer, well-formed features on the leeside. The local morphology that diminished the leeside corner eddy occurrence involved two, two-story trees that were growing on the leeside corners of the subject building when the field design was created, approved and preparations initiated. Unfortunately, these trees were unexpectedly removed just prior to the field study execution. The net results were the discovery of a much larger leeside

corner eddy without the trees, and a better understanding of how the trees had been combing the air into a smaller, well-defined eddy.

The lessons learned from the airflow qualitative assessment took the form of recommendations for future data analysis. Some of these recommendations documented in ARL-TR-4441 (Vaucher et al., 2008) were as follows:

- There is a need to reexamine each feature outside their idealized conditions and to start linking the various features together for their interdependencies.
- There is a need to reexamine all airflow parameterizations with winds starting above calm levels and to analyze each feature under non-ideal westerly Fetch conditions as a means for bringing "new" airflow feature characteristics to light. Specifically, the VAD characterization would be richly enhanced if the VAD were analyzed as a function of various wind directions and starting Fetch velocities.
- The ideal Cavity Flow was defined as westerly flow aloft (10 m AGL) and easterly flow near the surface (2.5 m AGL). With the field test design favoring local prevailing winds from the southwest, an alternate flow reversal pattern would be to have southwesterly winds aloft and northeasterly winds near the surface. Extending this concept further, investigating the occurrence of a northwest-upper and southeast-lower Cavity pattern would also be very informative.
- Finally, inter-feature flows, such as the continuous pattern of the VAD, Cavity Flow, and RAZ, need to be explored.

In summary, the airflow qualitative assessment explored the horizontal and vertical nature of the dynamic data by confirming the ideal patterns of each targeted airflow feature. Based on the lessons learned (recommendations), the opportunities for expanding our understanding of the airflow around a single urban building are just starting.

2.3.2 Stability Qualitative Assessment Results and Observations

A long term goal of the WSMR urban studies was to define, and ultimately forecast, an urban stability diurnal cycle. The first two studies, the *White Sands Missile Range 2003 Urban Study* (*W03US*) and the *White Sands Missile Range 2005 Urban Study* (*W05US*), showed a mix of rural (stable nights, unstable days, two neutral/transition periods) and city (unstable and neutral environments) stability patterns around the common subject building. The presence of an urban stable environment prompted the need to better understand the character and idiosyncrasies of this less frequent yet very real attribute. Thus, the stability qualitative assessment became a stable environment qualitative assessment. The reasoning was that once the ill-defined feature was better understood, a more coherent picture of the diurnal urban cycle would be easier to discern, and a resolution for the two originally dichotomous conditions (rural and city stability cycles) observed around the small urban building complex could be reached.

In the previous section, the observation was presented that there were less high velocity wind events during *W07US* than in the earlier two *Studies*. Unlike airflow, the stability characterization opportunities seemed to increase under these climatologically atypical conditions. ARL-TR-4452 (Vaucher et al., 2008) provides a description of the *W07US* stable qualitative assessment results. However, these results are more easily understood when they are contrasted against the earlier field studies and subdivided into spatial and temporal perspectives.

There were no consistent spatial patterns found in all three of the field studies. There were, however, consistent patterns observed between seasonally similar field study atmospheric environments. For example, the spatial distribution during the climatologically windy field studies showed a preference of stable conditions on the east (leeside) of the subject building. The open environment of the east side suggested an increased potential for radiative cooling with respect to the other "enclosed" building sides.

The atypical climatological conditions (light winds) of the *W07US* favored the west (Fetch) side of the building. The proposed explanation for these contrasting results suggested that the heat from the radiating building lacked the airflow necessary to send the heat away from the building. Therefore, all sides but the Fetch integrated the added heat into the vertical profiles and reported less stable conditions than the non-building influenced Fetch (west) side.

The temporal distribution of the stable environment between the three field studies was extremely consistent. The first preferred time period for occurrence was 2100–0259 LT (nighttime). The second preferred was 0300–0859 LT (sunrise). In two of the *Studies*, there was a third preferred of 1500–2059 LT (sunset). No *Study* reported stable conditions during the daytime period (0900–1459 LT).

After defining a "case"' as a period of consecutive atmospherically stable minutes, an inter-*Study* comparison showed an amazing consistency in the average case length. That is, the consecutive stable minute cases were between 6–8 min in length. In sharp contrast, the maximum case durations between towers and field studies varied greatly. The North tower reported a maximum case duration of 14 min during *W03US*. The longest case duration was 312 min and was reported in the *W07US* Southwest tower data.

In summary, these above observations were reduced to the following list of spatial and temporal characteristics:

Spatial Characteristics

1. During windy conditions, the building leeside was favored for stable environments.
2. During non-windy conditions, the building windward (Fetch) side was favored for stable environments.
3. The roof with a heating vent generated a stable environment.

Temporal Characteristics

4. The most populated period for stable environment occurrence was midnight, ±3 h.[‡]

5. Second most populated period for stable environment occurrence was sunrise, ±3 h.

6. The average duration of consecutive minutes for stable conditions was 6–8 min.

7. The extreme durations for consecutive stable minutes ranged from 14–312 min.

8. Extreme stable case durations favored the non-windy environments.

As with the airflow qualitative assessment, "lessons learned" and recommendations were gleaned from the stability qualitative assessment. Three of the recommendations for future analysis included the following:

1. *Diurnal stability cycle*: The next step in the stability analysis is to investigate the spatial distribution under purposefully non-windy conditions. Such ambient scenarios favor the generation of a stable environment and would, therefore, better expose the diurnal cycle of the stability.

2. *Roof stable environments*: The anthropologically induced stable environment on the roof may prove useful to those who need to exploit stable environments. A more detailed review of the roof conditions during the data acquisition period may better define the causes and effects involved in generating the urban stable conditions.

3. *Temporal stable environment character*: The next step, which is already being investigated by the current researchers, involves tightening the temporal scale of the stable distribution.

3. Discussion

The term "data processing" can generate a wide variety of expectations across the many scientific disciplines. In section 1, the definition used for the *W07US* data processing was outlined with respect to the overall *W07US Test Plan*. We return to that explanation to re-cap the procedure and elaborate on some of the intended purposes for the various data processing steps.

The data processing procedure chosen first accounted for the data resources in terms of sensor and DAS selections. With the goal of ensuring the highest quality of data available, these data were anchored by requiring a relative calibration of all sensors before and after the field study

[‡]Preliminary findings from subsequent research indicate that the most populated period may be refined to 0000–0300 LT. A preview of these research results, see ARL-TR-4452 (Volume AS-2) (Vaucher et al., 2008).

execution. The initial evaluation of the sampled data was to identify, correct and, if needed, replace any non-functioning sensors. Unlike the previous field study, there were no sensors that needed to be replaced during *W07US*.

The next phase of the data processing procedure involved the daily data monitoring. This monitoring required significant forethought due to the extremely large amount of data that was to be generated. Issues involving each variable’s format, consistent time stamps for multiple locations and DAS, storage strings, non-interrupting data downloading techniques, and large data storage units with backup storage spaces were just a few of the details that had to be meticulously addressed. Trial runs for this data monitoring phase were critical in generating an efficient enough procedure to accommodate the very large dataset that was anticipated.

Note: For the technology at the time of *W07US*, the daily data monitoring procedure took four trained professionals, working a steady 4–5 h, using five computers with two operating systems, two printers (all data was printed out for documentation and review purposes), five 2.5 in. notebooks (all pre-sectioned), a whiteboard for the daily team notes/discussion/etc, and the cooperative support of the sponsoring administration.

The Post-*W07US* data processing was intended to be sequential, but with time constraints and limited human resources, was conducted in parallel. The subsequent documentation for these parallel efforts was already cited in the above text. The documentation regarding the main dataset quality was the topic of this report. The three key features, chosen for publication, carry a double function. That is, not only do they document the features, but they are intended to aid in the future use of the data. The survey contains important reference nomenclature to identify the data files and explain any gaps that may occur within a data period of interest. The averaging section contains an important lesson learned in time-aligned averaging for those interested in correlating multiple tower and tripod data resources soon after the field study is completed. And finally, the data trend section contains important observations and suggestions for future research. These gems are intended to encourage collaborative work that will advance the urban meteorological understanding.

Now that the data processing phase is nearing its completion, there were several observations and lessons learned worth noting. For example, the extremely low amount of missing data for both the thermodynamic and dynamic datasets was most encouraging. The implication of this attribute supports the concepts that the both the commercial-off-the-shelf (thermodynamic) and the “office built” (dynamic) data acquisition systems were robust and reliable. Collecting data from such systems provides a favorable potential for a high quality dataset.

There was a lessoned learned regarding the use of the NTP for time stamping. Reducing the input/output time required for updating the system clock is an area for improvement. Another lessoned learned involved the need to time-align the averages used in the daily data monitoring efforts. If time-aligned 1-min averages were used during the monitoring phase, this would eliminate the need to recalculate averages for the Post-*W07US* data processing and analysis.

The qualitative assessments not only served the data processing goal of documenting any measurement problems, but they also contributed to the scientific objectives of validating the presence of airflow features and better characterizing the stable environments around a single building.

4. Conclusions

This report completes the initial series of documentation for the *W07US* field project and its data processing results. Since the term "data processing" can generate a wide variety of expectations across the many scientific disciplines, the definition *W07US* utilized was outlined and explained within the context of the *W07US Test Plan*. In short, the *W07US* data processing began with the inception of the field study, continued through the extensive data acquisition period, and persisted through this Post-*W07US* data evaluation effort. Independent documents citing concurrent data processing activities included an overview of the field study preparation and execution (Volume 1), a document of the calibration data processing and results (Volume DP-1), a document of the airflow qualitative assessment (Volume DP-3), and a document of the stability qualitative assessment (Volume AS-2).

This document (Volume DP-2) focused on the three key areas of the *W07US* main dataset's Post-*W07US* data processing efforts: the data survey, the data averaging, and the data trends. The data survey divided the 32 GB of data into two categories: the dynamic data and the thermodynamic data. These categories were distinguished by their DAS. Missing data from each category were tabulated as a function of causes. For the dynamic data, six causes were identified to explain the less than 2% of missing data. The single occurrence of missing thermodynamic data was declared insignificant (less than 0.01%; only 2 min were missing!).

The data averaging efforts required an evaluation of the data time stamps. The time stamp for the dynamic data utilized a non-internal source. Consequently, there were occasional data alignments with nonlinear time stamps. Using the philosophy that all data is valued, these "added" data were preserved and were subjected to a time synchronization routine when averaged. The time stamp for the thermodynamic DAS was internal and therefore experienced only linear time stamping.

The data trends explored both the horizontal and vertical attributes of the overall main dataset. With such a massive amount of data over a relatively short spatial area, the decision was made to utilize the targeted airflow features as dynamic data reference points. This method was equivalent to the astronomer's technique of using stars and star clusters to map the heavens. All seven primary flow features were statistically assessed for their frequency of occurrence, as a function of a sampling day. Table 8, in section 2.3.1, summarized the results. All airflow

features were present on each day of the *W07US* data acquisition period. This initial qualitative assessment defined each feature in its ideal form. Several suggestions for future investigations were identified in the form of observations and recommendations.

The thermodynamic data trends were examined through spatial and temporal perspectives. With an underlying goal of defining and being able to predict an urban diurnal stability cycle, the data trend investigation focused on the unusual urban character of a stable atmosphere around a building. The results from the earlier two field studies conducted at the same test site and during the same month as *W07US* were weighed into the assessment. This added information provided the needed contrast for extracting the stability patterns. Eight urban, single building, stable environment characteristics were identified. These included the following:

Spatial Characteristics

1. During windy conditions, the building leeside was favored for stable environments.
2. During non-windy conditions, the building windward (Fetch) side was favored for stable environments.
3. The roof with a heating vent generated a stable environment.

Temporal Characteristics

4. The most populated period for stable environment occurrence was midnight, ±3 h.[§]
5. Second most populated period for stable environment occurrence was sunrise, ±3 h.
6. The average duration of consecutive minutes for stable conditions was 6–8 min.
7. The extreme durations for consecutive stable minutes ranged from 14–312 min.
8. Extreme stable case durations favored the non-windy environments.

Quality data was the goal for the *W07US* data processing effort. After examining both the dynamic and thermodynamic datasets, we believe that the data acquired has the potential to enrich many different types of urban research projects. For this reason, we have added a data survey tool in appendix E: daily plots of the *W07US* Southwest tower (a.k.a., Fetch tower) wind speed and wind directions. These 24 h time series are intended to assist potential data users in identifying periods of atmospheric conditions suitable for their research objectives. For further information regarding the use of the *W07US* dataset, please contact the authors of this technical report.

[§]Preliminary findings from subsequent research indicate that the most populated period may be refined to 0000–0300 LT. A preview of these research results is included in ARL-TR-4452 (Vaucher et al., 2008).

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Wikipedia-the free encyclopedia, Beaufort Wind Scale. http://en.wikipedia.org/wiki/Beaufort_Wind_Scale (accessed January 9, 2008).

Appendix A. *W07US* Schematic Layout With Images of Tower/Tripod Structures

Three airflow patterns were designed into the *W07US* layout, as well as a 360° stability sampling around and above the subject building. In figure A-1, a schematic of the horizontal *W07US* urban field site is drawn. Figures A-2 and A-3 show a top down (overview) schematic of the *W07US* urban field site, along with the flow patterns and photographs of the towers/tripods involved in the flow pattern. A-4 shows the entire layout with all the photographic images.

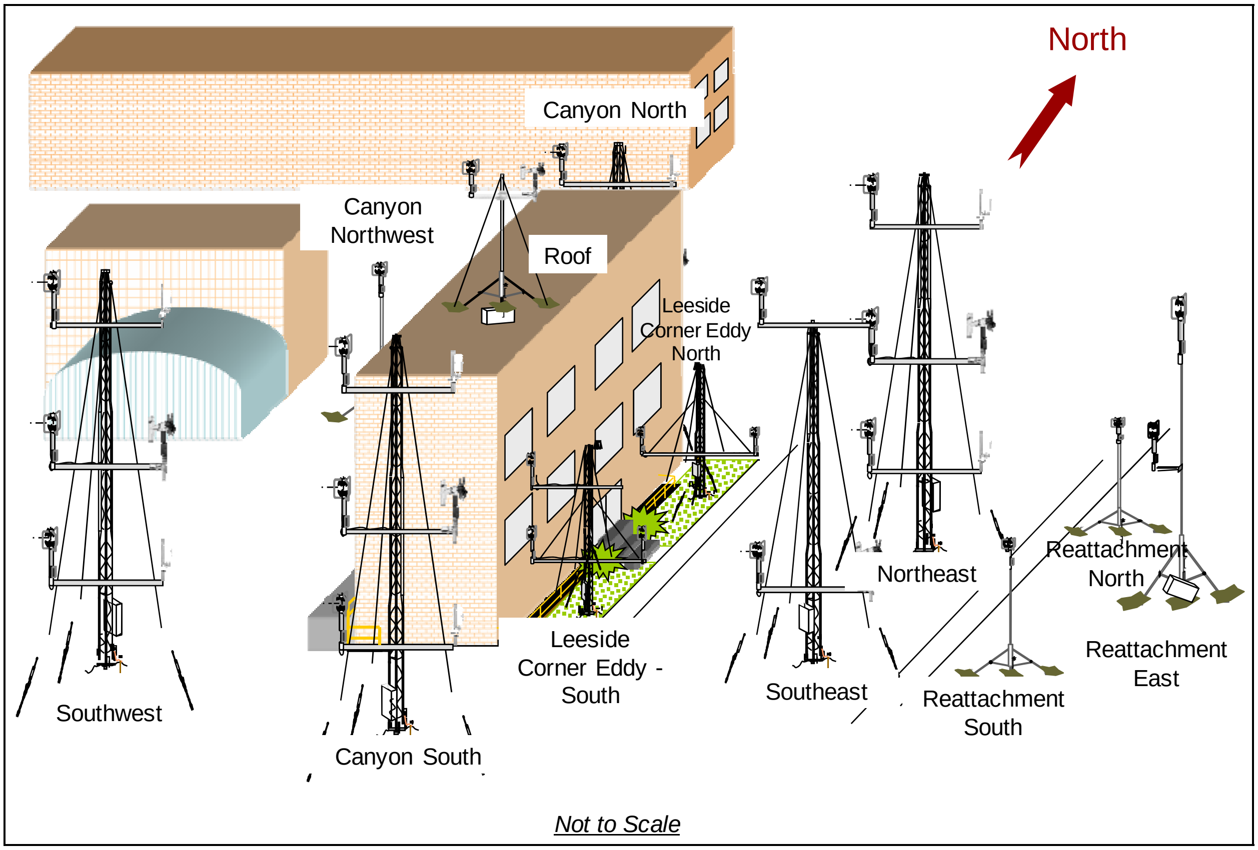

Figure A-1. *W07US* field site layout: A side view schematic.

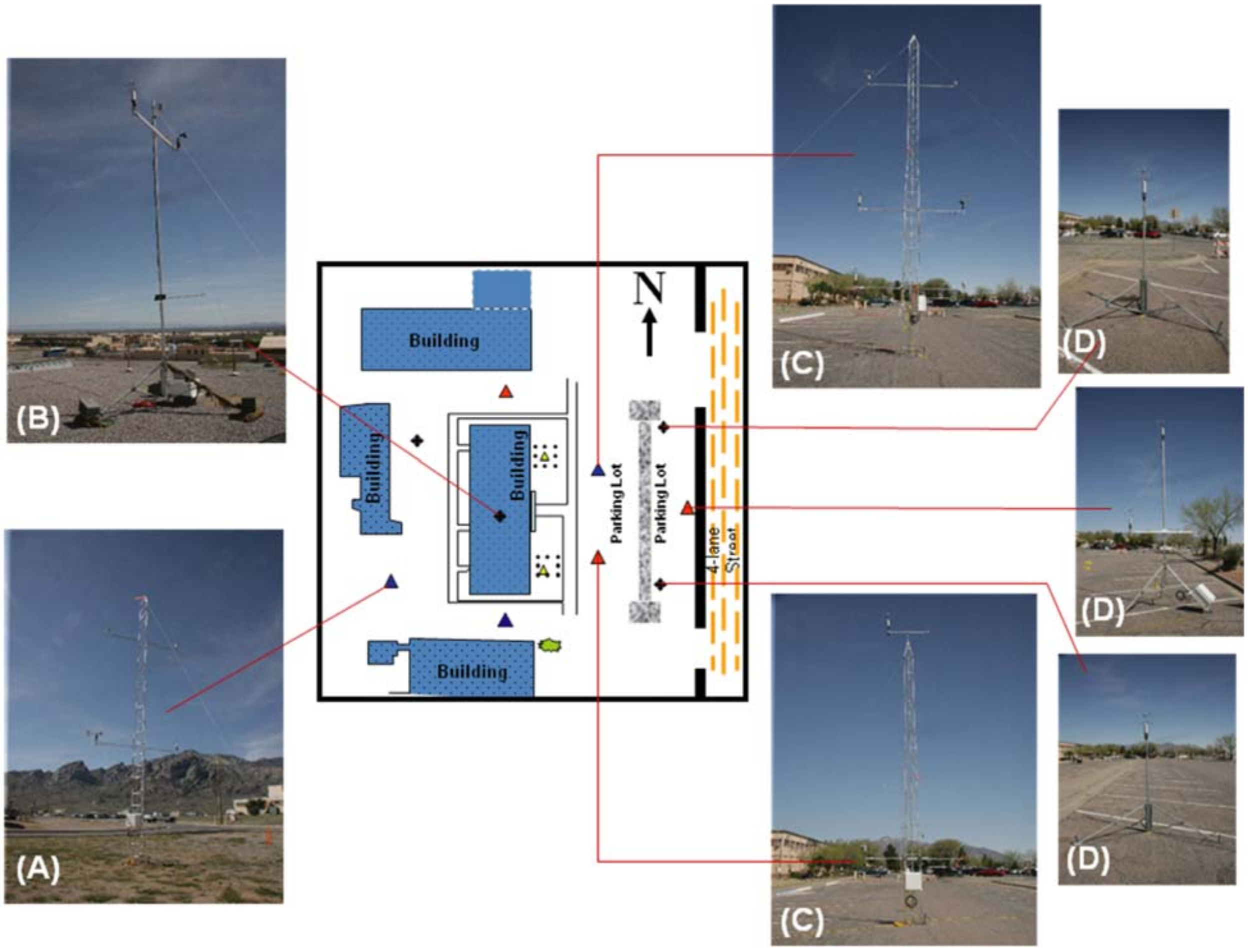

Figure A-2. *W07US* flow pattern 1: Fetch flow (A) precedes the building; airflow accelerates over the roof (Velocity Acceleration-(B)), then slows on the building leeside (Velocity Deficit-(C)) and forms a flow reversal (Cavity Flow-(C)); and airflow resumes its original character at the Reattachment Zone-(D).

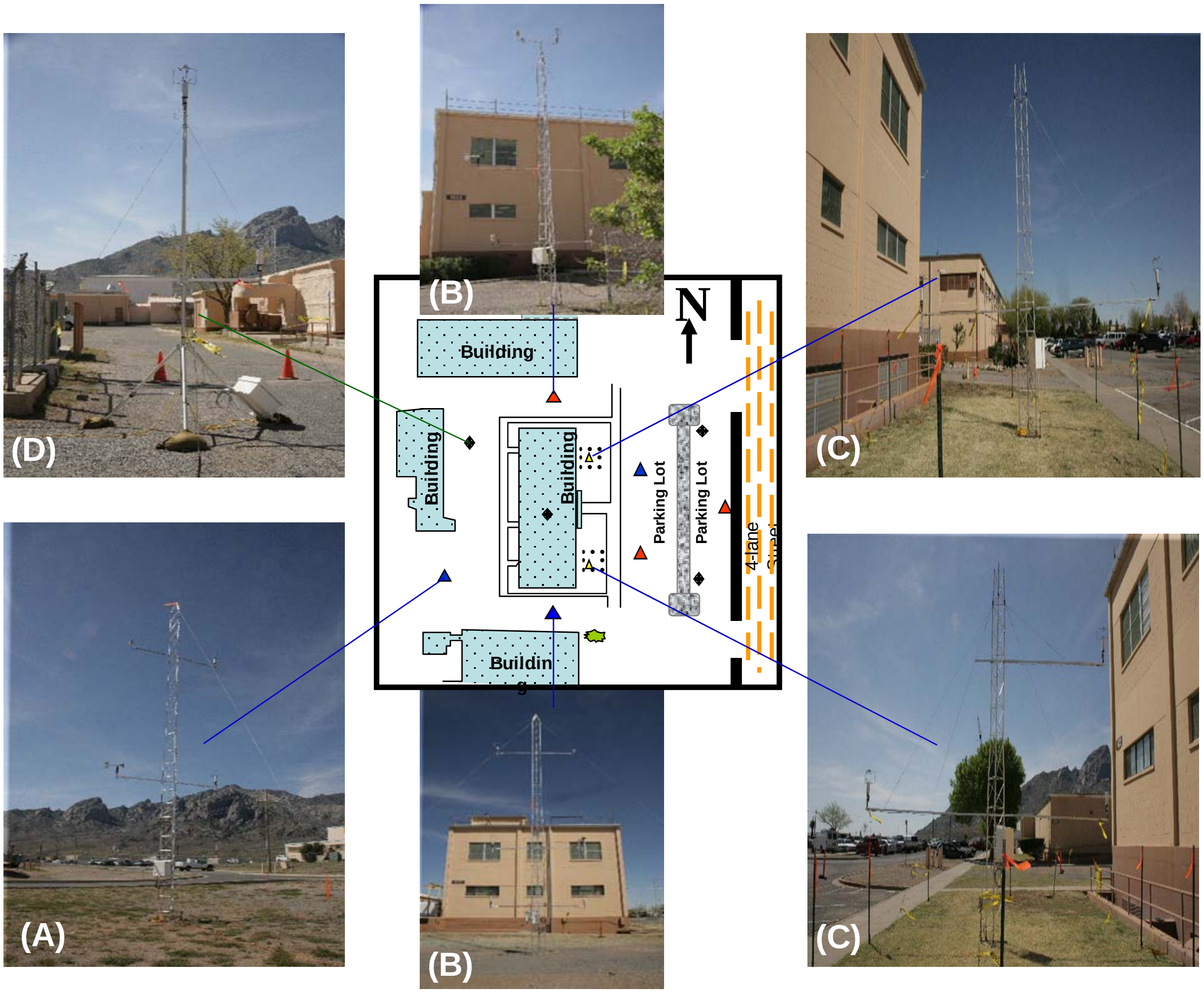

Figure A-3. *W07US* flow pattern 2: Fetch flow (A) precedes the building and airflow accelerates between buildings (Canyon Flows-(B)) then forms corner eddies/vortices on the building leeside (Leeside-Corner Eddies-(C)). *W07US* flow pattern 3 begins with a westerly fetch flow then travels along the windward canyon between the buildings (Canyon-West-(D)).

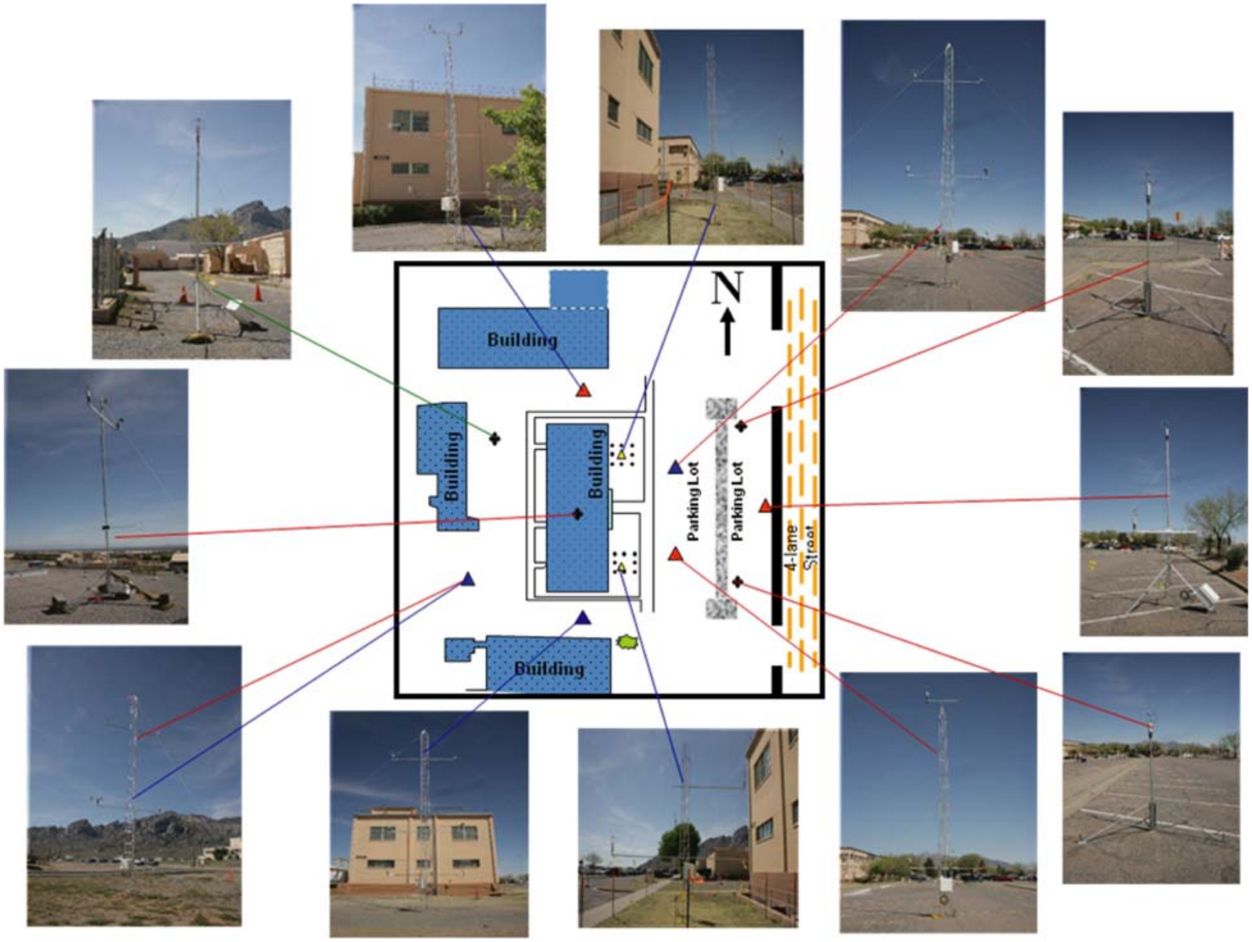

Figure A-4. *W07US* flow patterns 1–3: Field site layout schematic with photographs of all tower and tripods.

Appendix B. Dynamic Data (Sonic) File Format

Section B-1 consists of a dynamic data file notation review (see section 2.1.1), a description of the dynamic data file format, and a dynamic data file sample.

B-1 Dynamic (Sonic) Data File Notation

W07US dynamic (sonic) data file names use the following pattern of notation:

Reference number_

Two letter tower code_

Sonic number_

Sonic height_

Date of data collection in the format of YYYYMMDD_

Starting hour in local time for data in file

.

Text (txt)

For example: A raw data file named "01_SW_1360_02m_20070325_0000.txt" would mean that the data in the file was acquired from the following:

- Reference number 1
- Southwest Tower
- Sonic number 1360
- Sonic height was 2.5 m (in default location: west of the tower structure)
- Data was collected on 2007 March 25
- This file's data started at 0000 LT (and extends one hour (0-59.999983 minutes only)
- .
- This is a text file.

B-2 Dynamic Data File Format

The format for the *W07US* dynamic data file content uses the following pattern:

Header: Line 1

YYYY MM DD HH MM SS (+u is W to E, +v is S to N)

2007 03 27 00 00 00 (+u is W to E, +v is S to N)

Data: Line 2-end:

Time (dec hr), u(m/s), v(m/s), w(m/s), Temperature (C), speed of sound (m/s)

00.000001 0.5900 0.0000 0.0600 16.79 341.82

B-3 A Dynamic (Sonic) Data File Sample

The first and last three lines of a *W07US* sonic data file:

```
2007 03 27 00 00 00 ( +u is W to E, +v is S to N )
00.000001    0.5900   0.0000   0.0600   16.79  341.82
00.000014    0.5000   0.0700   0.1000   16.76  341.80
…………
00.999957    0.6600  -0.1700   0.0700   15.28  340.92
00.999970    0.7100  -0.2400   0.0200   15.28  340.92
00.999983    0.6600  -0.2600  -0.0100   15.25  340.90
```

Appendix C. *W07US* Sonic Locations by Horizontal (Tower) and Vertical (Height) References

Table C-1. Sonic locations by horizontal (tower) and vertical (height) references.

WSMR 2007 Urban Study (W07US)

Sonic Count	W07US Tower Reference Number	Chronological Sonic Serial Number List	Horizontal Location Tower	Vertical Location* Height (m AGL)	Orientation Position on Tower/Tripod	Calibration Status
1	12	0637	NW	5	center	NIST Calib
2	12	0638	NW	2.5	west	NIST Calib
3	2	1330	SS	10	west	NIST Calib/Old Standard
4	2	1338	SS	5	west	-
5		1341				NIST Calib-*W07US* Standard
6	2	1342	SS	2.5	west	-
7		1343				Spare Sonic
8	4	1353	NN	2.5	west	-
9	4	1354	NN	10	west	-
10	3	1355	NE	2.5	west	-
11	3	1356	NE	5	west	-
12	3	1357	NE	10	west	NIST Calib
13	1	1358	SW	5	west	-
14	1	1359	SW	2.5	west	-
15	1	1360	SW	10	west	NIST Calib
16	6	1361	SE	2.5	west	-
17	6	1362	SE	10	west	-
18	10	1368	VS	2.5	east	-
19	10	1369	VS	2.5	west	-
20	10	1370	VS	5	west	-
21	11	1371	VN	2.5	east	-
22	11	1372	VN	2.5	west	-
23	9	1373	RN	2.5	center	-
24	5	1374	RR	6	center	NIST Calib
25	8	1375	RE	2.5	west	-
26	8	1376	RE	5	center	-
27	7	1377	RS	2.5	center	-

* For more detailed heights, contact *W07US* Test Director.

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Appendix D. Thermodynamic Data File Format

Section D-1 recaps the thermodynamic data file notation (see section 2.1.2), describes a thermodynamic data file format and provides a sample from a thermodynamic data file.

D-1   Thermodynamic Data File Notation

W07US thermodynamic data file names use the following pattern of notation:

At the time of this writing, the thermodynamic data were organized into two forms: a continuous stream of data by tower, and a set of daily data files by tower. Both the continuous stream of data and the daily data files begin at the official start of the field study, 2007 March 19 (midnight), and end at the official field study conclusion, 2007 April 1 (midnight). The only difference is the file content: the "continuous" files contain no break in between the start and end points; the "daily" files contain only a midnight to midnight period of the data. The two data endpoints were chosen to align the thermodynamic data with the dynamic data.

The raw *W07US* thermodynamic data file names use the following pattern:

- Micro-logger number_
- Tower code_
- Date of data collection in the format of YYMMDD_
- .
- Text (txt)

So that file "4650_SW2_070319.txt" means that the data in this file came from micro-logger number 4650, which was mounted on the Southwest tower, and contains data from 2007 Mar 19 (00:00 to 23:59 LT). Note: The added "2" indicates that there were two types of solar radiation sensors used on this tower. The default (without a "2") indicates only one solar radiation sensor was utilized.

D-2   Thermodynamic Data File Format

The thermodynamic data files contain several formats, depending on the sensor resources. The fully instrumented towers use the following comma delimited format:

- Station number
- Julian Day
- HHMM

- Pressure (mb)
- Temperature T107 Probe (°C) – upper level
- Temperature Vaisala HMP45AC (°C) – lower level
- Relative Humidity HMP45AC (%)
- Wind Speed (m/s)
- Wind Direction (°)
- Solar Radiation (W/m2)
- Net Radiation (W/m2)
- Battery Voltage (V)
- Panel Temperature (°C)

The vertical structures with a subset of the fully instrumented tower follow the same format as above, with the data from the absent sensors data removed from the comma delimited data string.

D-3 A Thermodynamic Data Sample

The first and last three lines of the thermodynamic data file *4650_SW2_070326* contained these data entries:

117,85,0,871.90,12.684,12.720,64.655,1.0927,318.13,-1.5603,-51.669,14.118,20.463

117,85,1,871.87,12.673,12.650,64.841,1.0617,317.18,-1.5723,-51.214,14.130,20.447

117,85,2,871.89,12.687,12.605,65.020,.93100,317.82,-1.4990,-50.698,14.149,20.430

………….

117,85,2357,869.70,17.143,15.743,25.447,1.4422,305.57,-1.0769,-73.757,14.260,22.140

117,85,2358,869.69,17.353,15.941,25.079,1.1531,298.94,.20042,-75.516,14.228,22.117

117,85,2359,869.70,17.418,16.115,24.779,.70723,279.06,.14508,-76.073,14.212,22.093

Appendix E. *W07US* Wind Speed and Wind Direction Data Plot Samples

Appendix E provides a glimpse of the atmospheric conditions that existed during *W07US*. Sonic wind speed and wind direction time series from the Southwest "Fetch" tower are graphically displayed for each day of *W07US*. The original data were sampled at 20 Hz; however, for practical reasons, the data plotted in appendix E are time-aligned 1-min average values. The Fetch tower was selected because of its scientific field design function. When climatological winds were present, the Southwest tower sampled the airflow prior to any interaction with the subject building. Thus, one can extract a general understanding of the initial airflow character just prior to its interaction with the urban structure. This data "pre-view" is intended to assist the urban atmospheric researcher who might be considering a proposal for utilizing the *W07US* data.

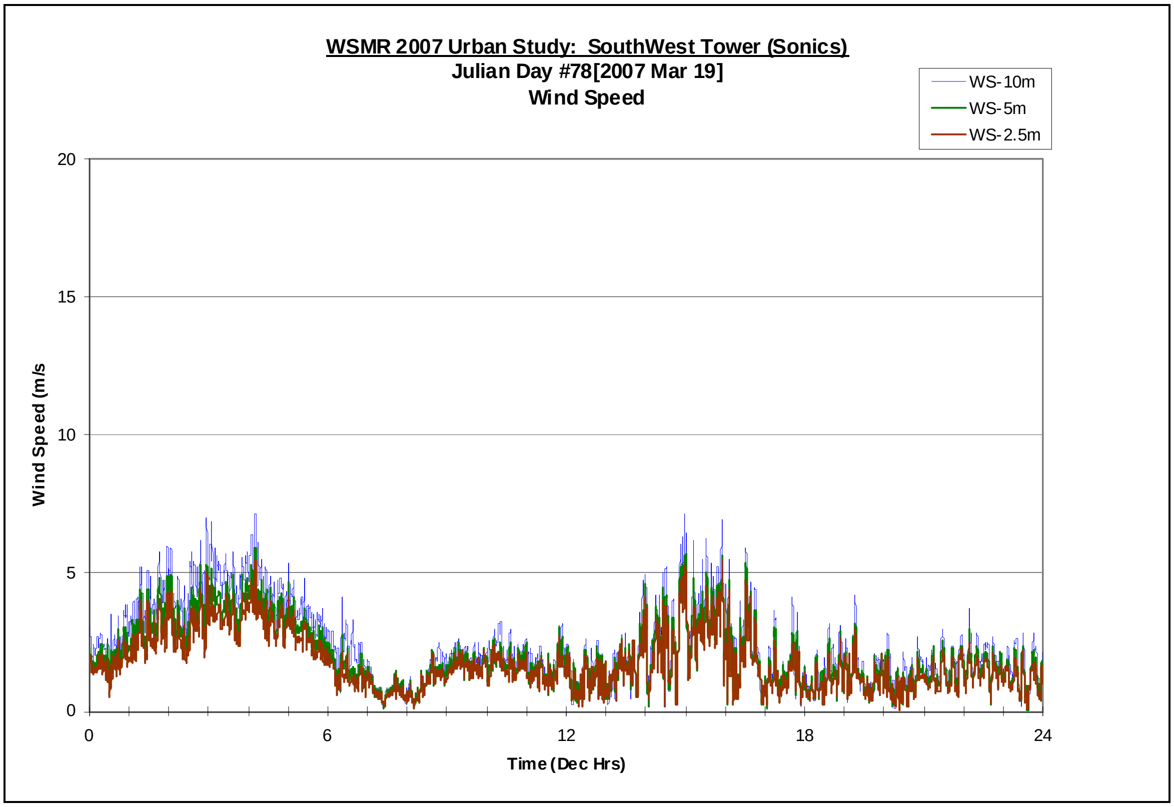

Figure E-1a. 2007 March 19, wind speed.

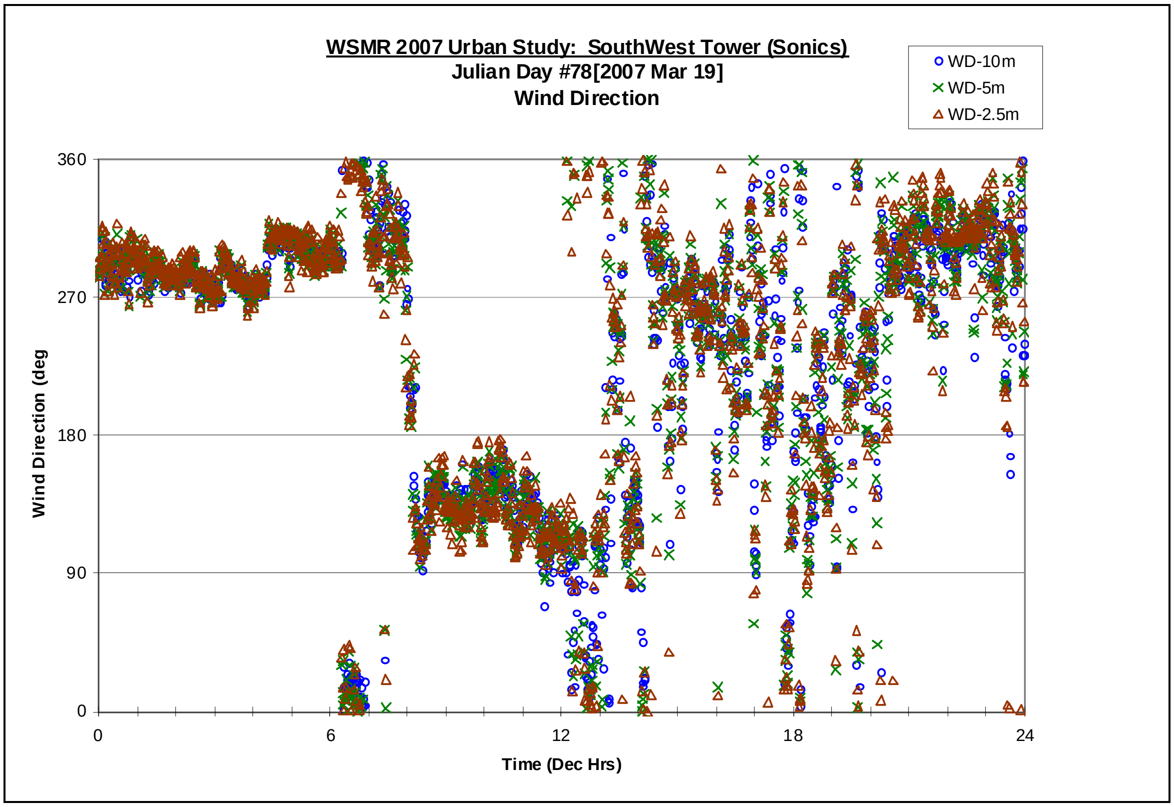

Figure E-1b. 2007 March 19, wind direction.

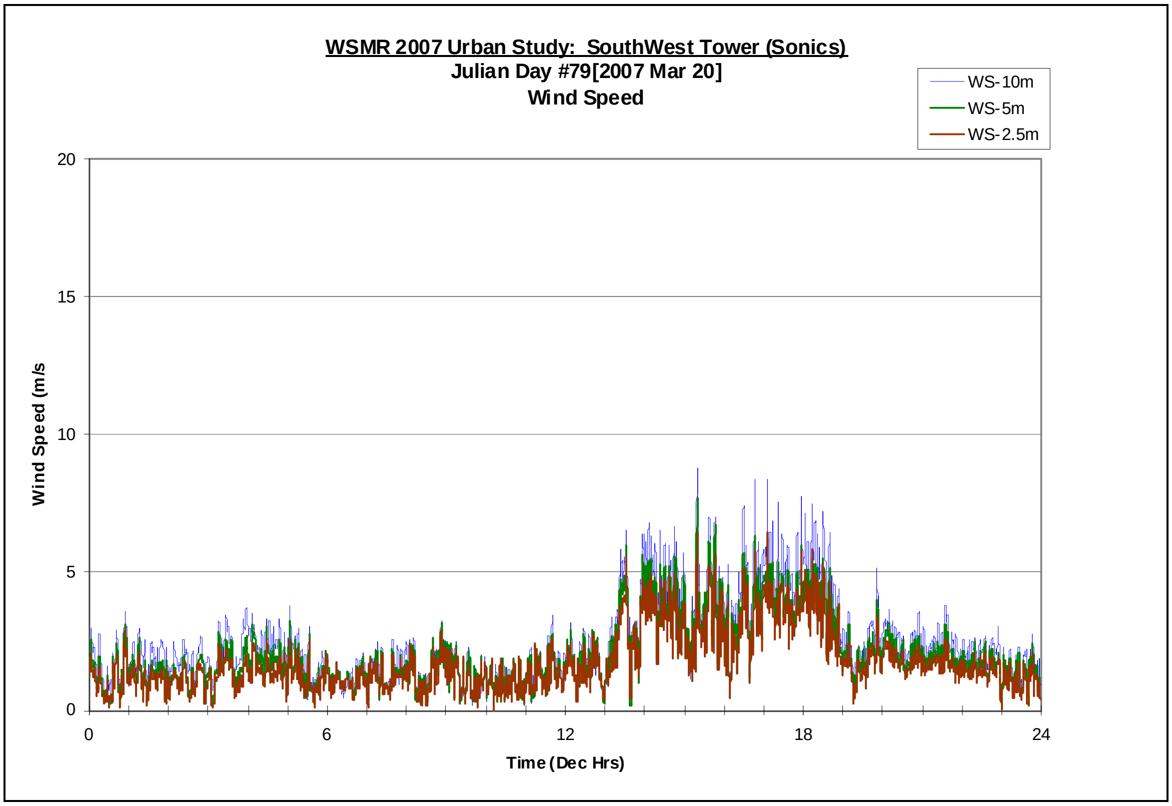

Figure E-2a. 2007 March 20, wind speed.

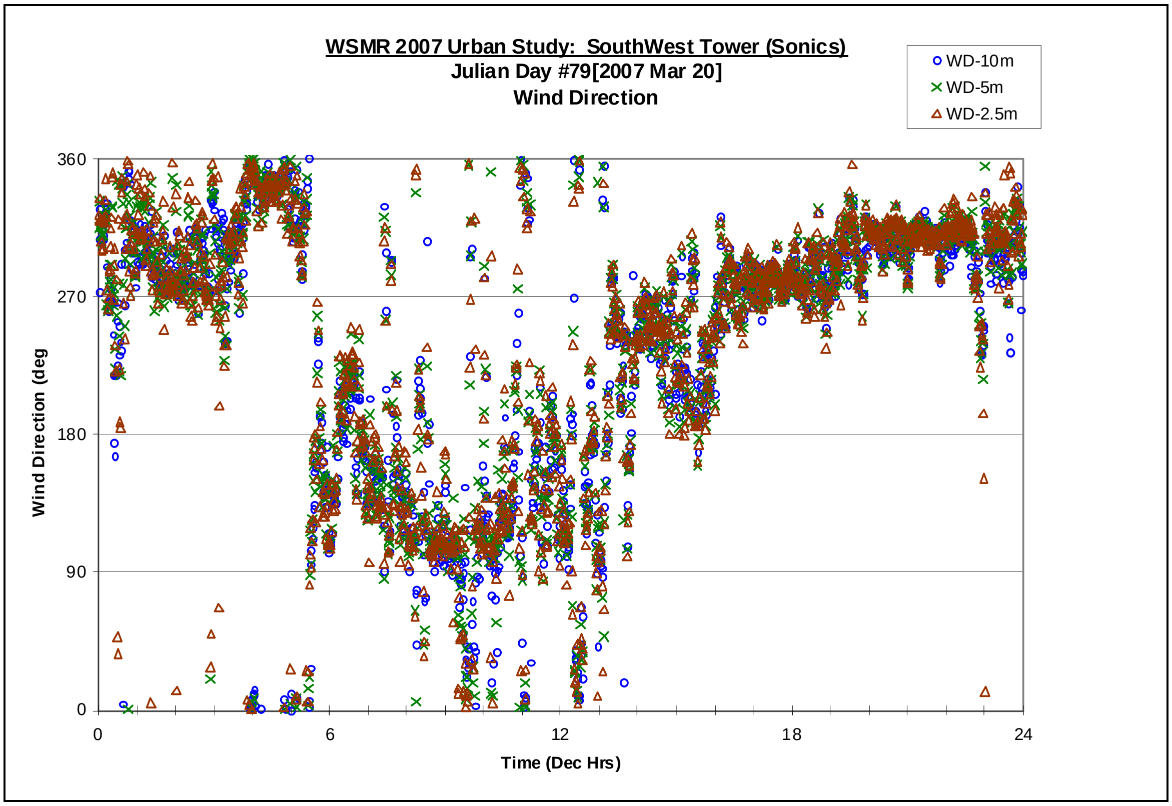

Figure E-2b. 2007 March 20, wind direction.

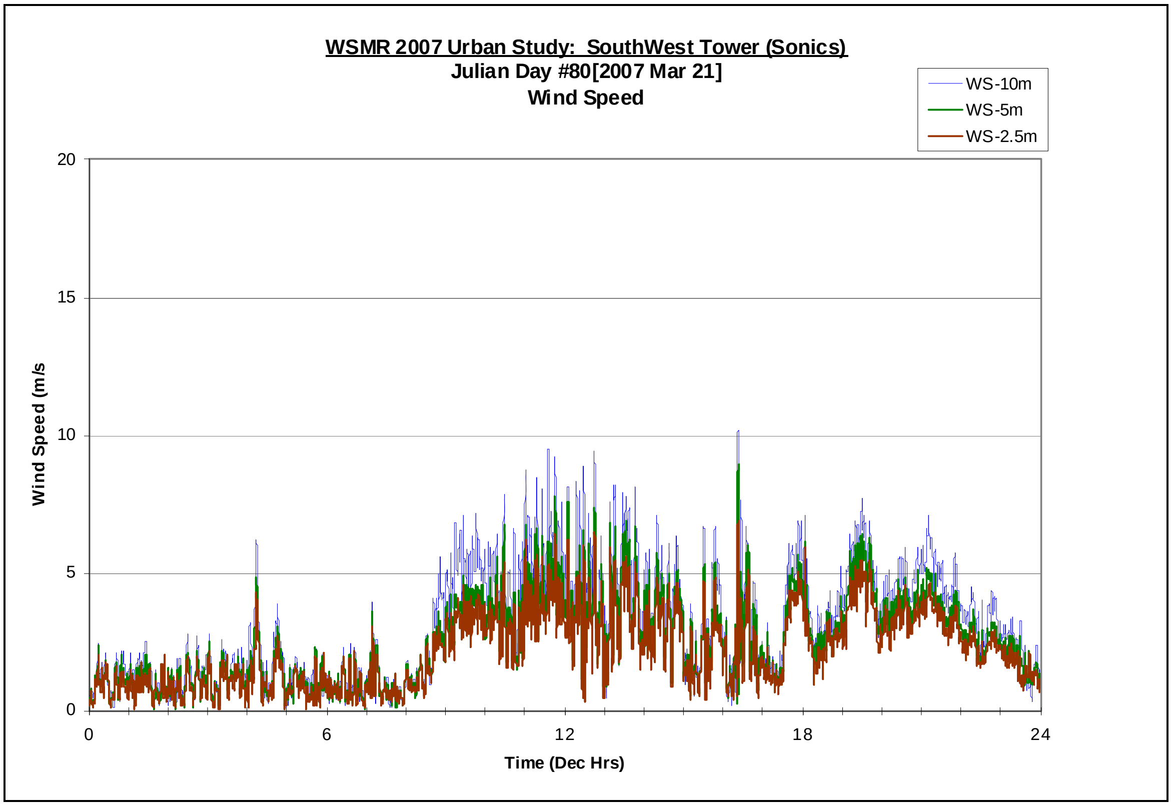

Figure E-3a. 2007 March 21, wind speed.

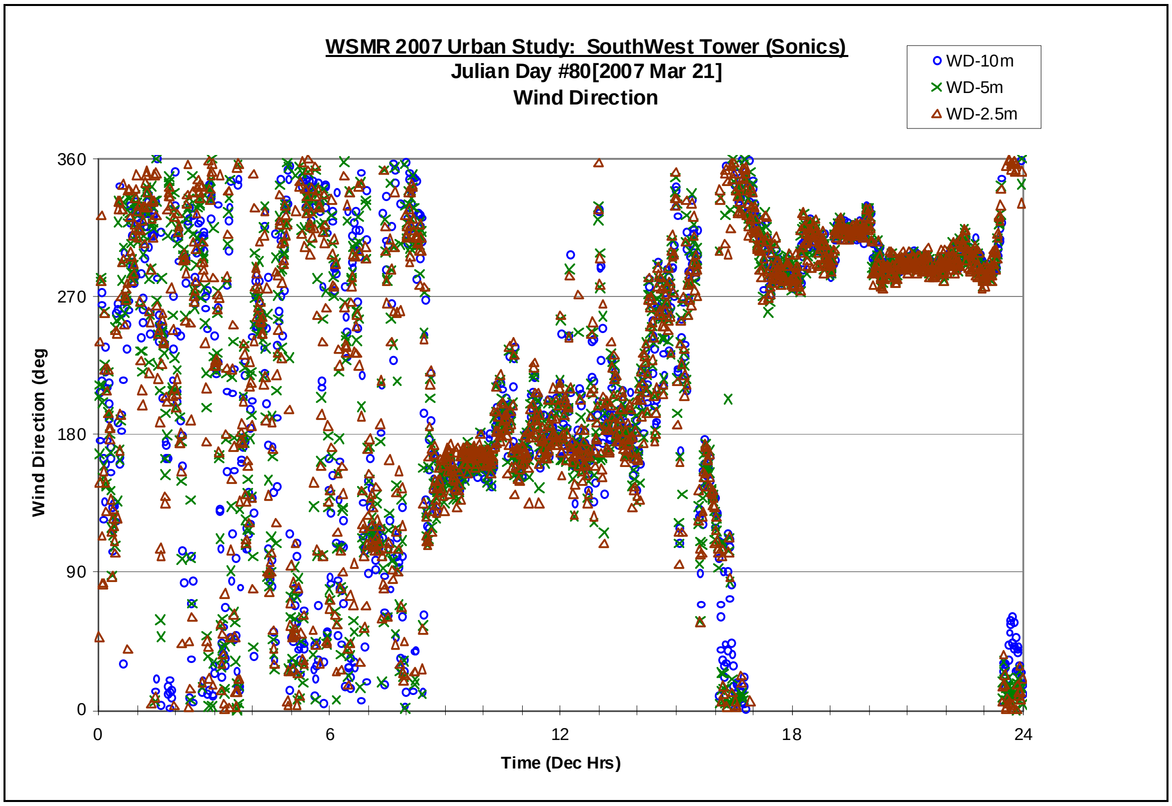

Figure E-3b. 2007 March 21, wind direction.

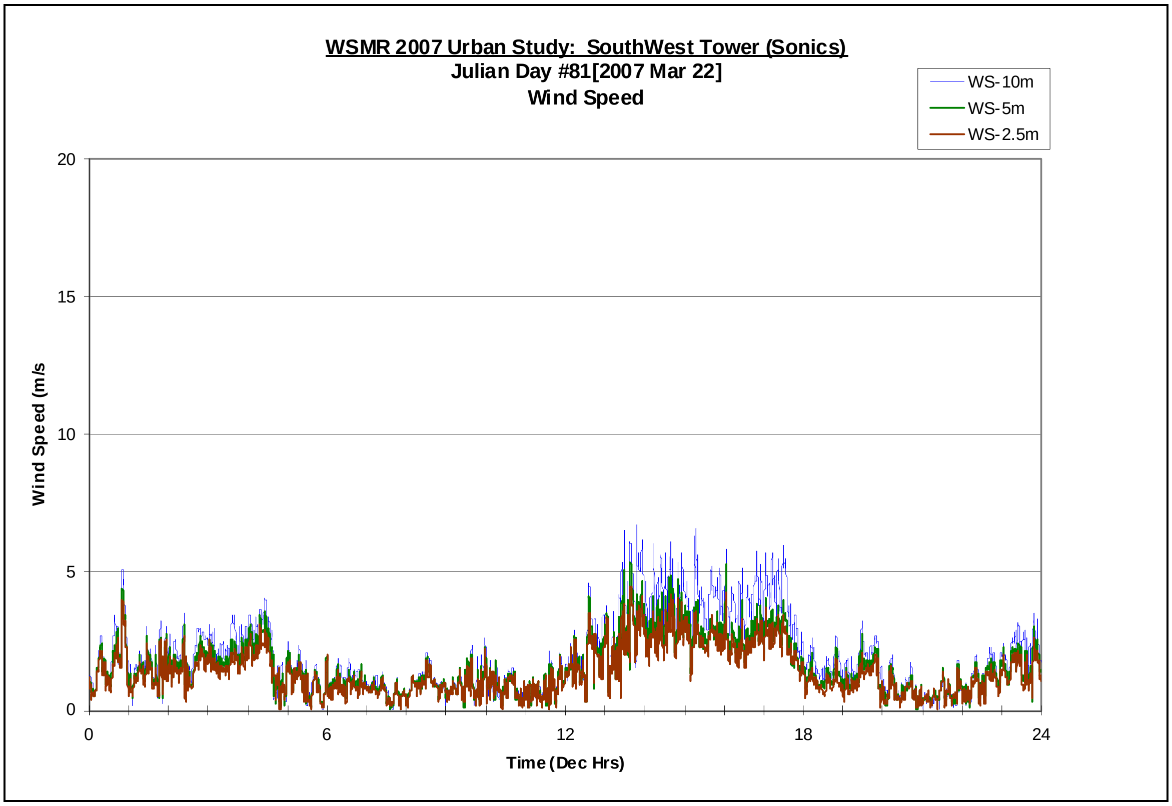

Figure E-4a. 2007 March 22, wind speed.

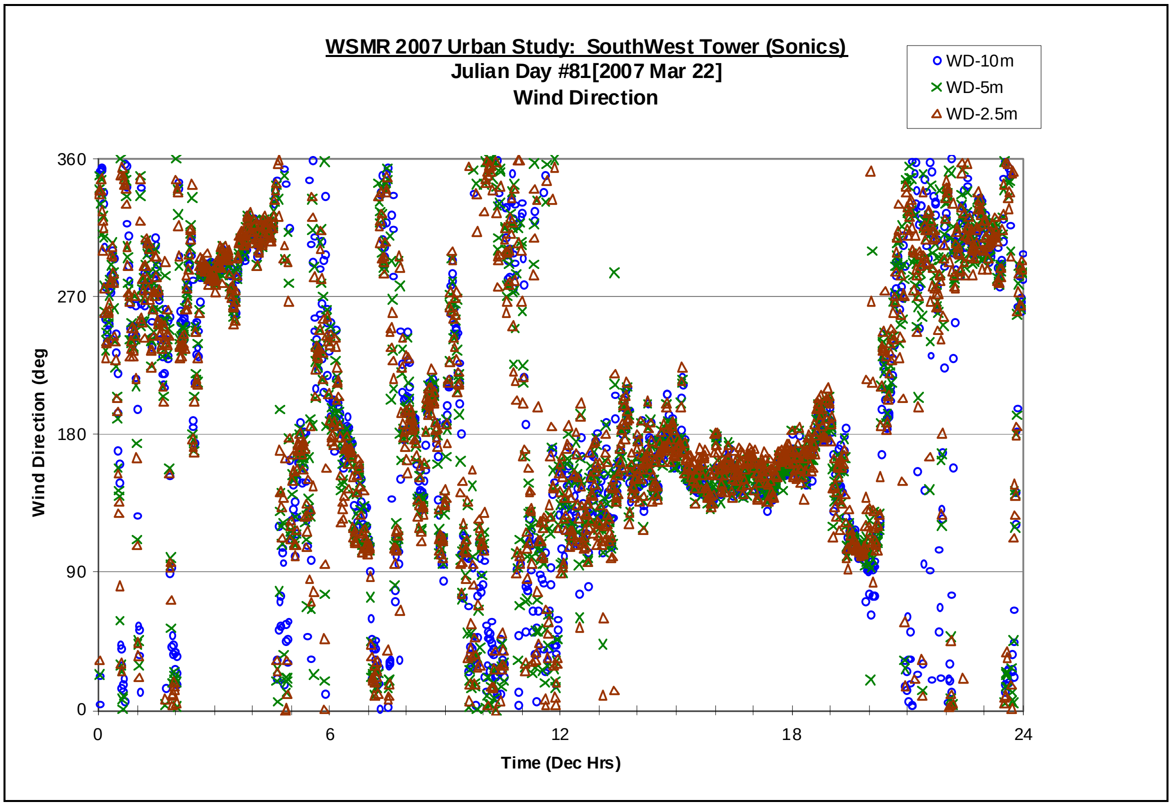

Figure E-4b. 2007 March 22, wind direction.

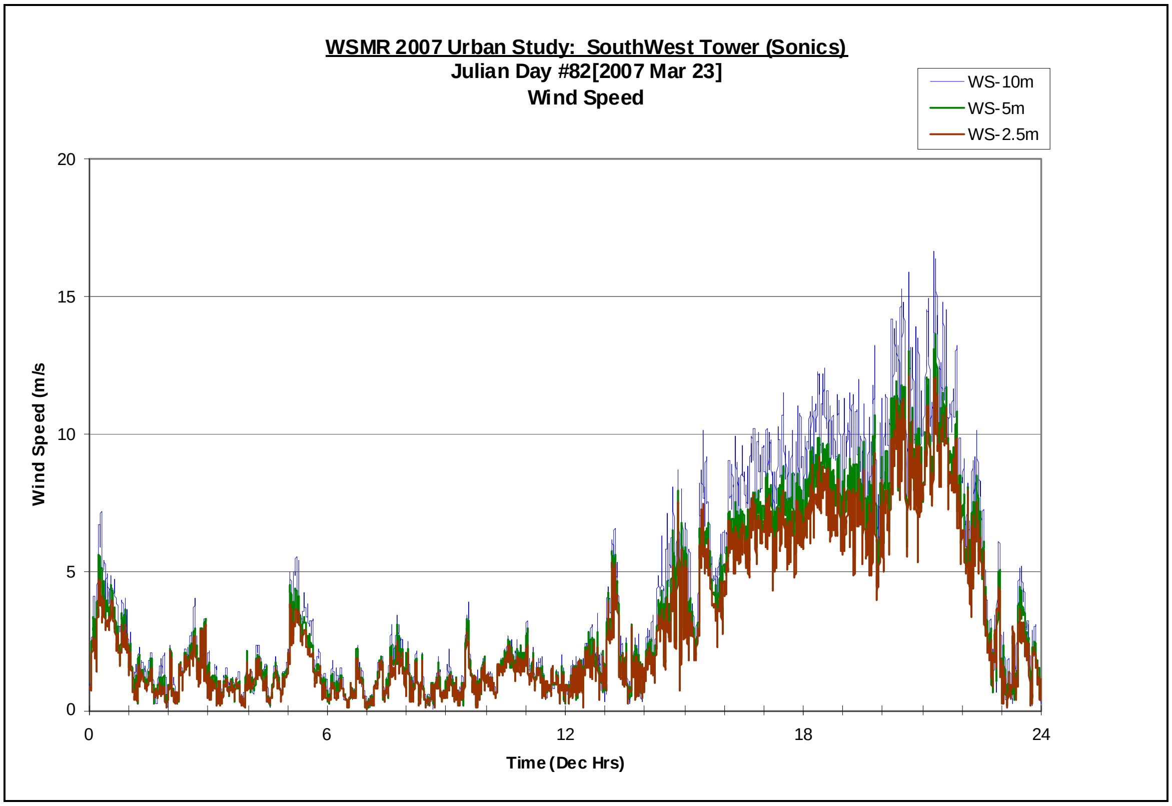

Figure E-5a. 2007 March 23, wind speed.

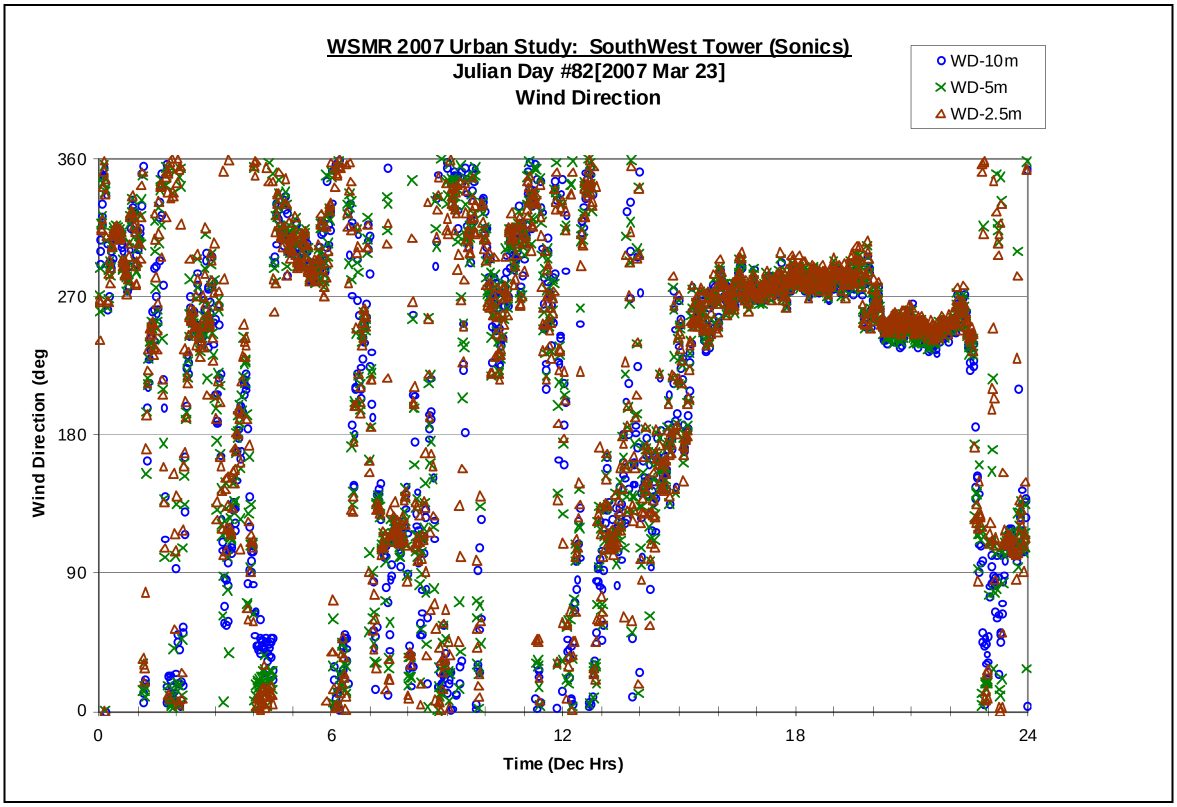

Figure E-5b. 2007 March 23, wind direction.

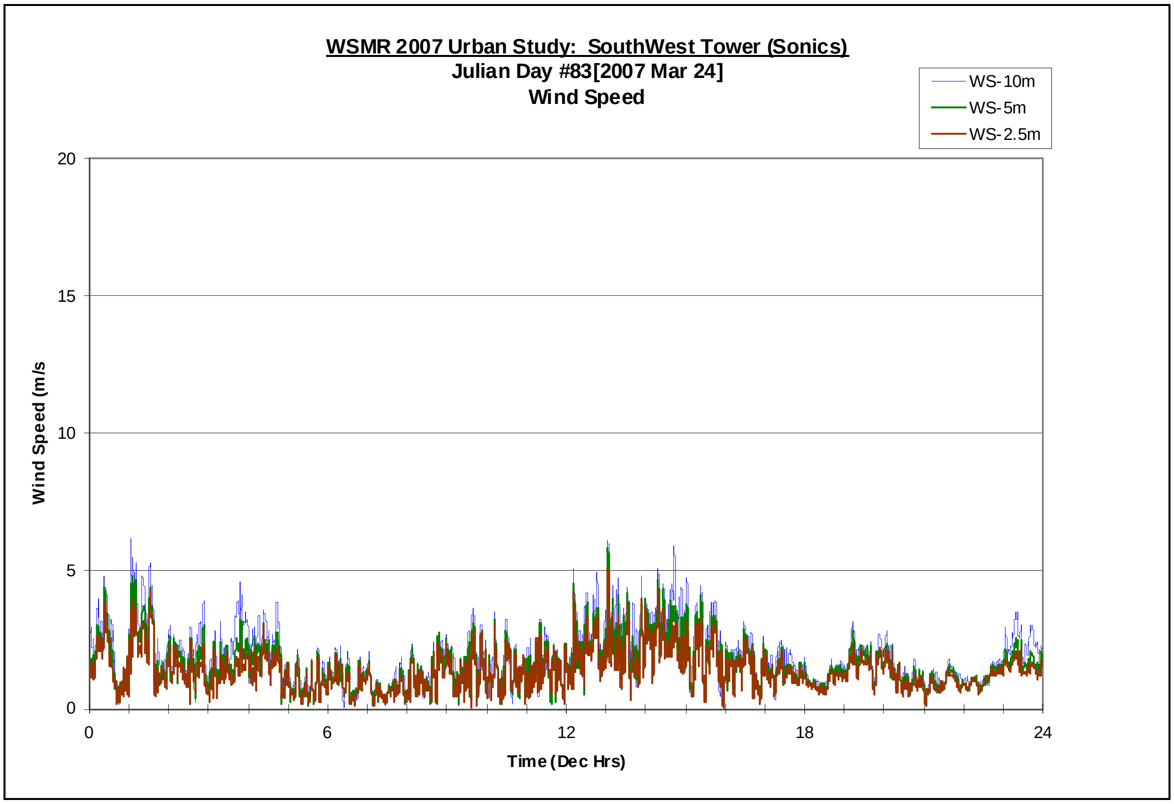

Figure E-6a. 2007 March 24, wind speed.

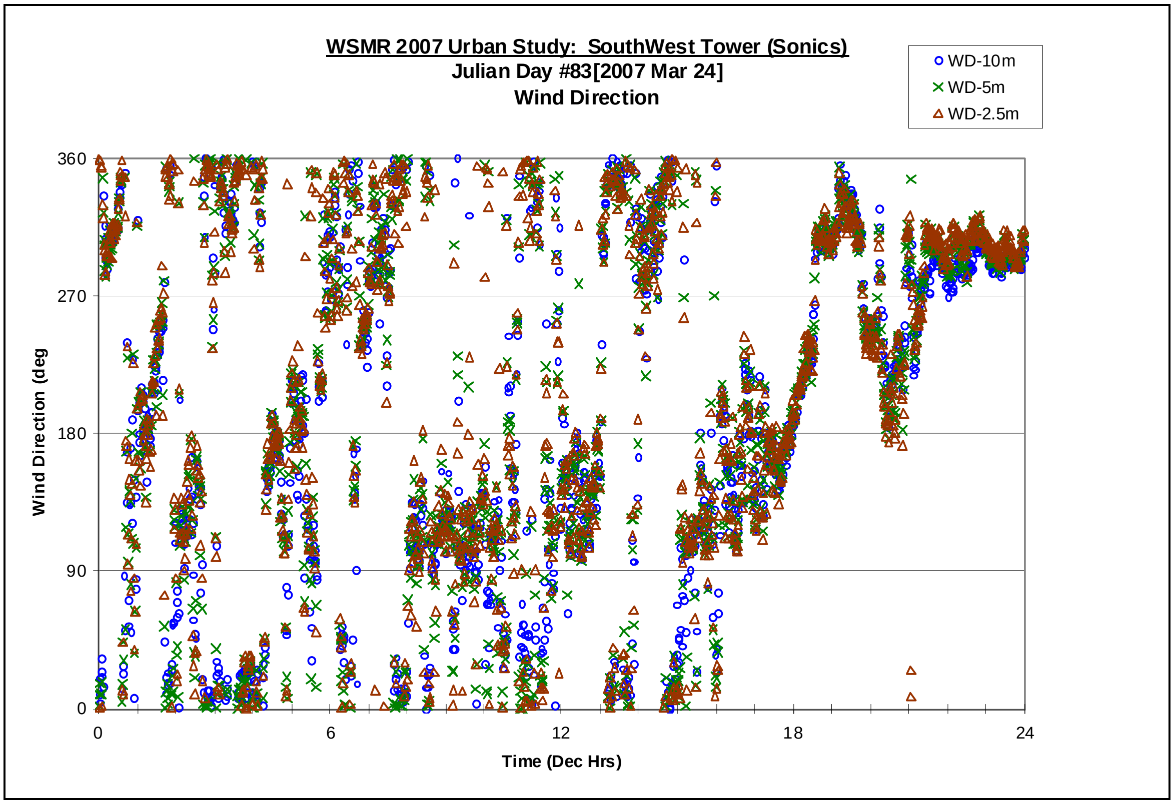

Figure E-6b. 2007 March 24, wind direction.

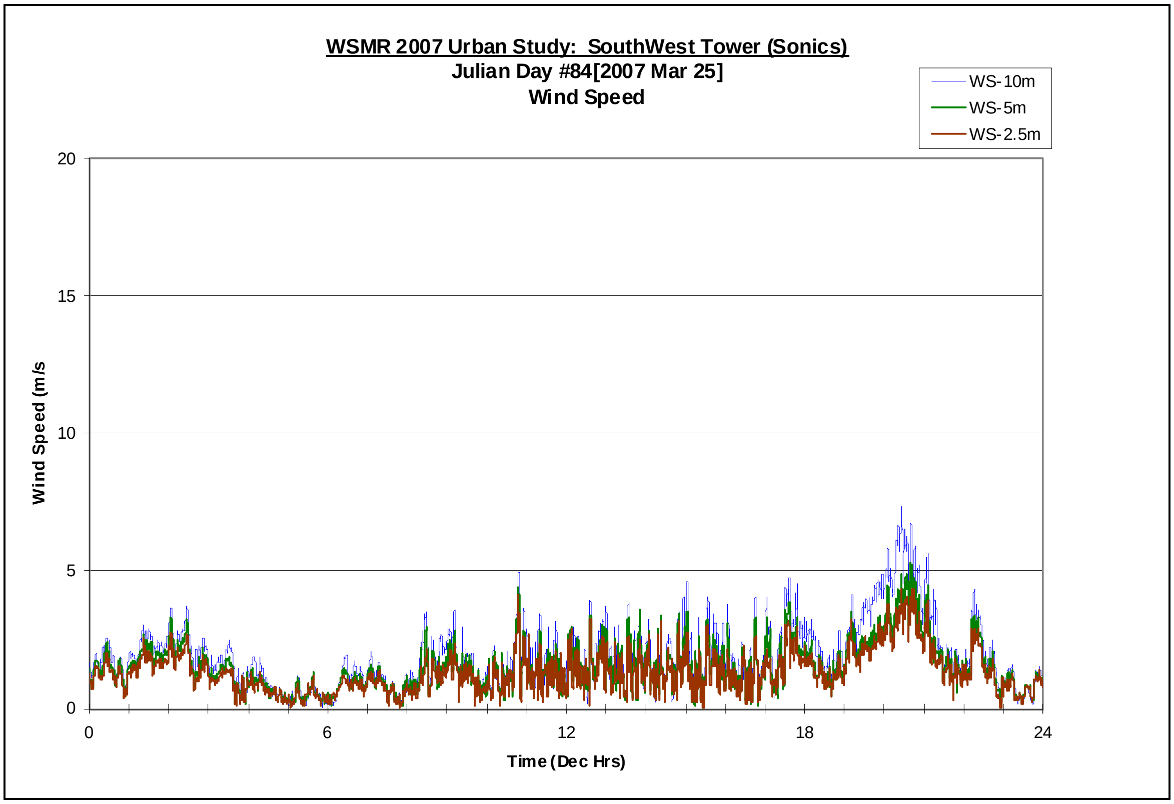

Figure E-7a. 2007 March 25, wind speed.

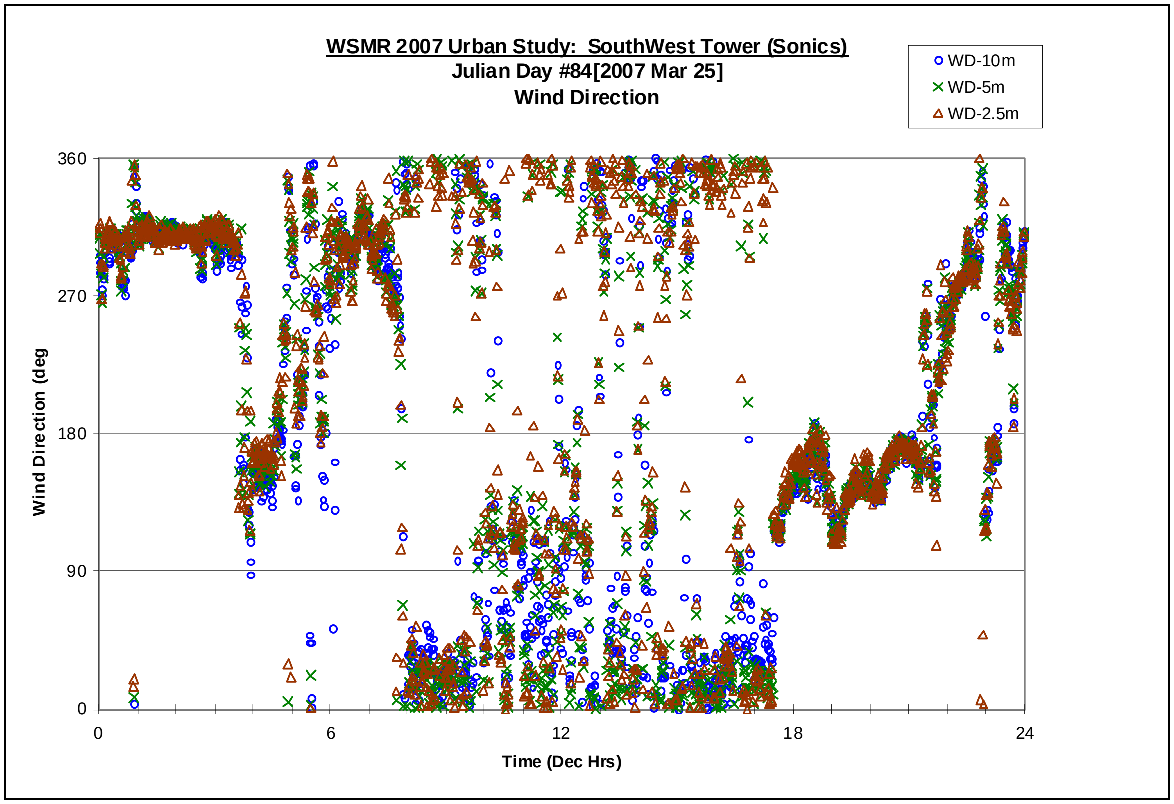

Figure E-7b. 2007 March 25, wind direction.

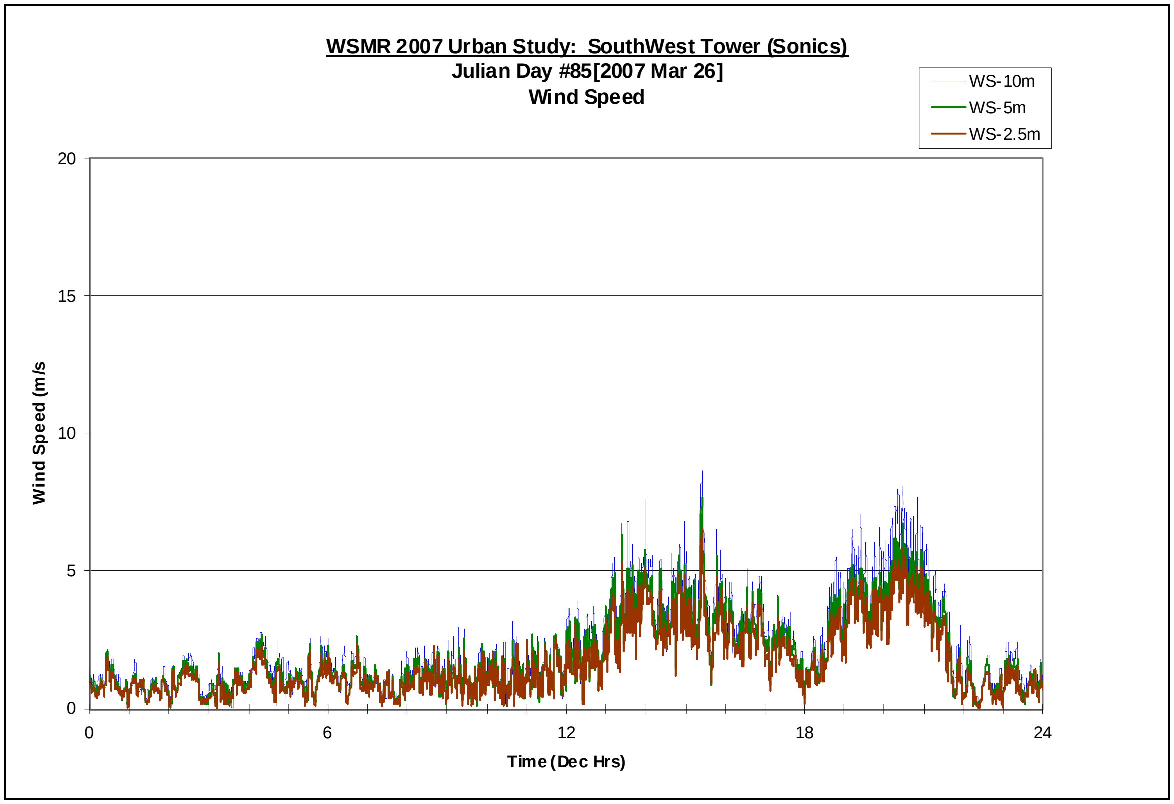

Figure E-8a. 2007 March 26, wind speed.

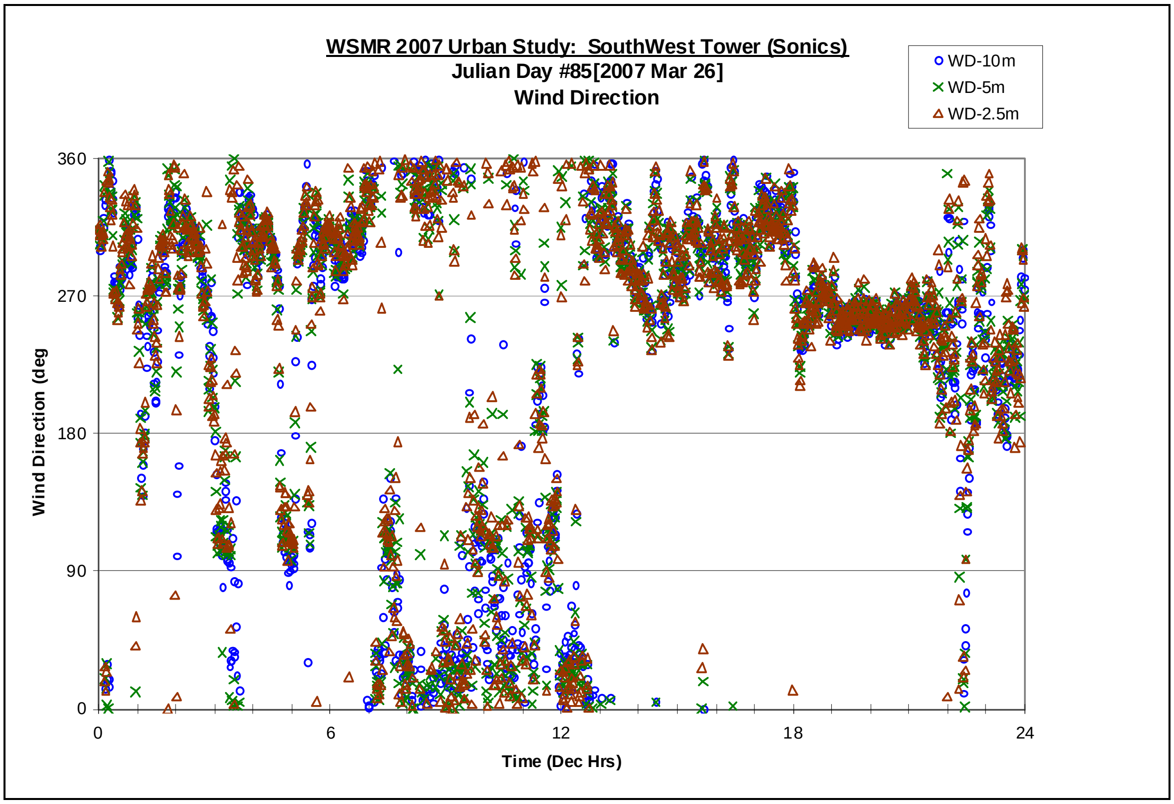

Figure E-8b. 2007 March 26, wind direction.

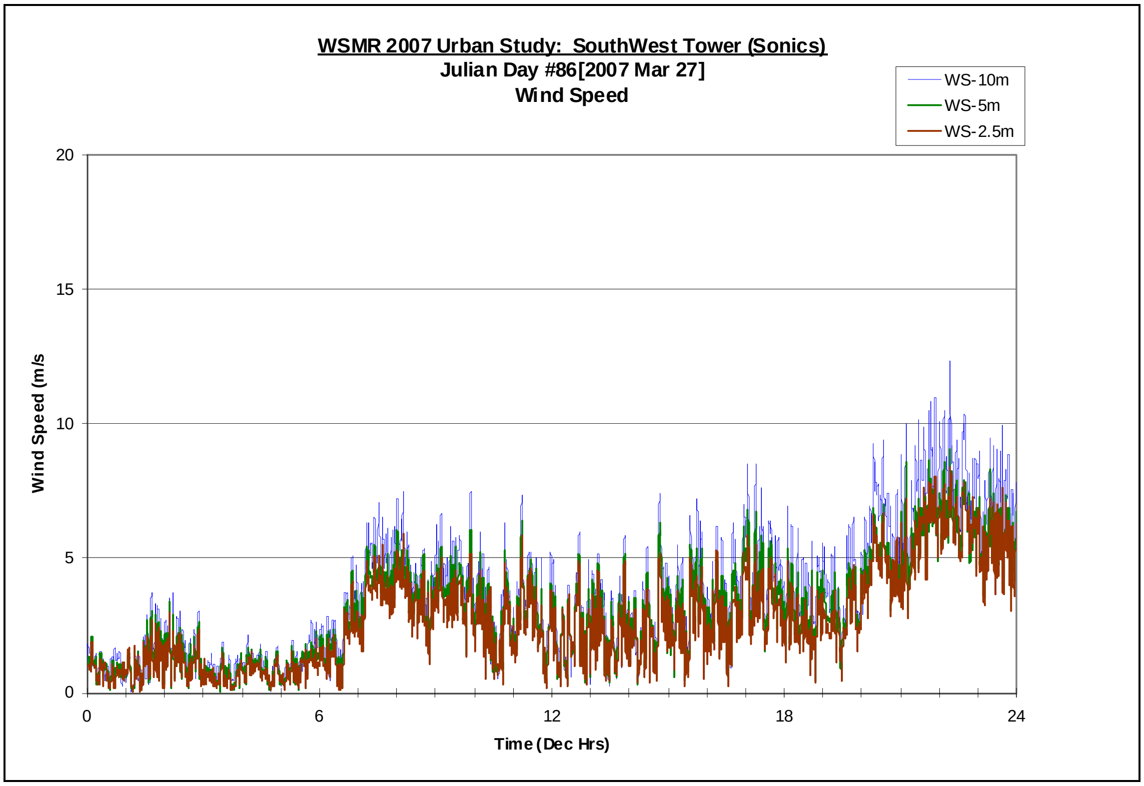

Figure E-9a. 2007 March 27, wind speed.

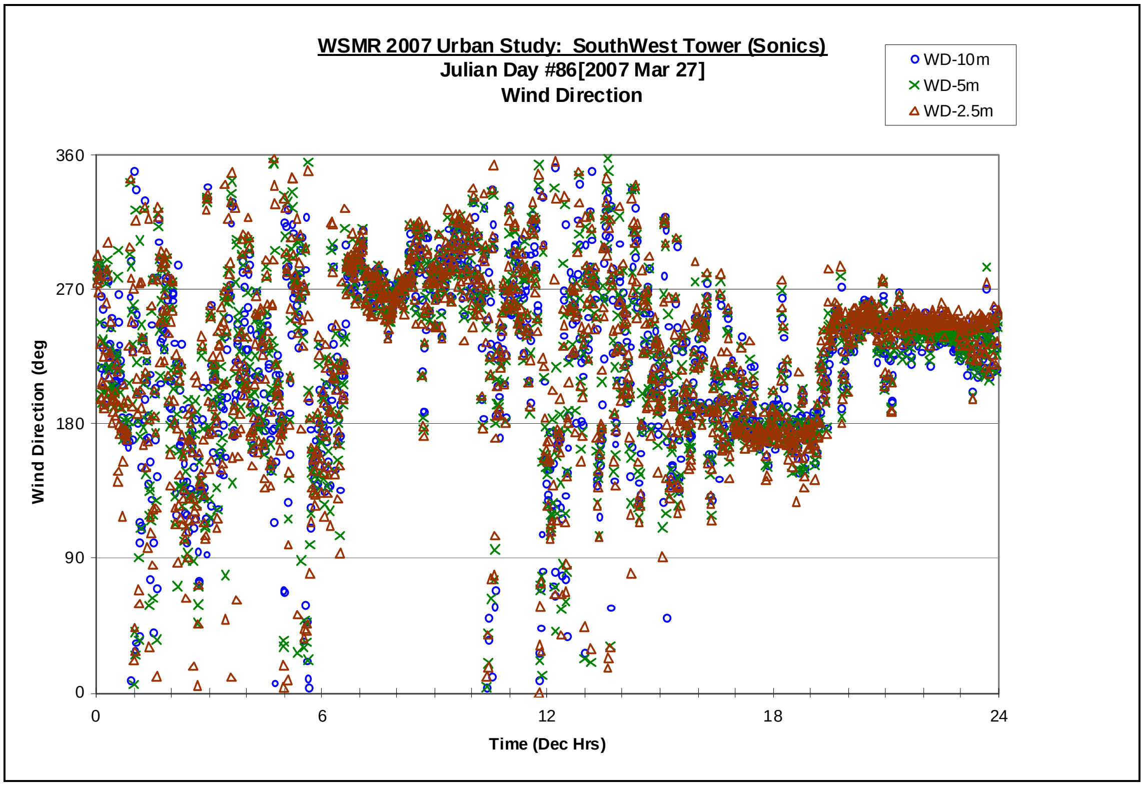

Figure E-9b. 2007 March 27, wind direction.

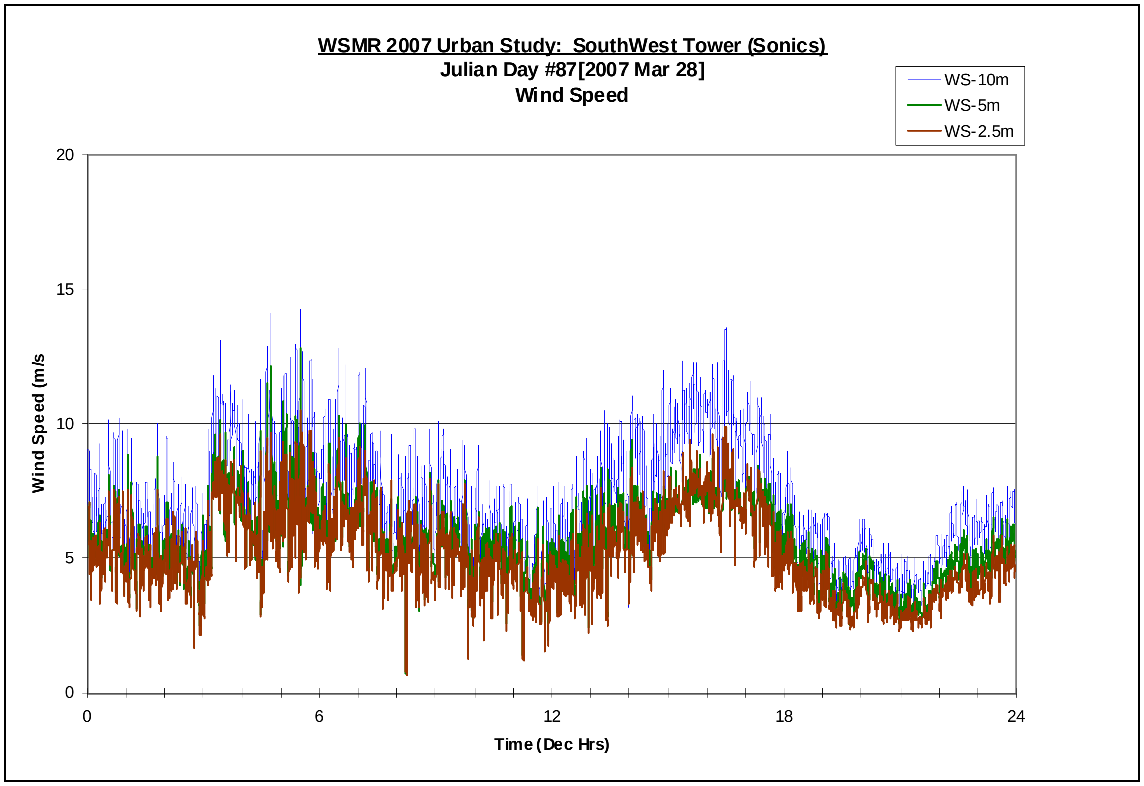

Figure E-10a. 2007 March 28, wind speed.

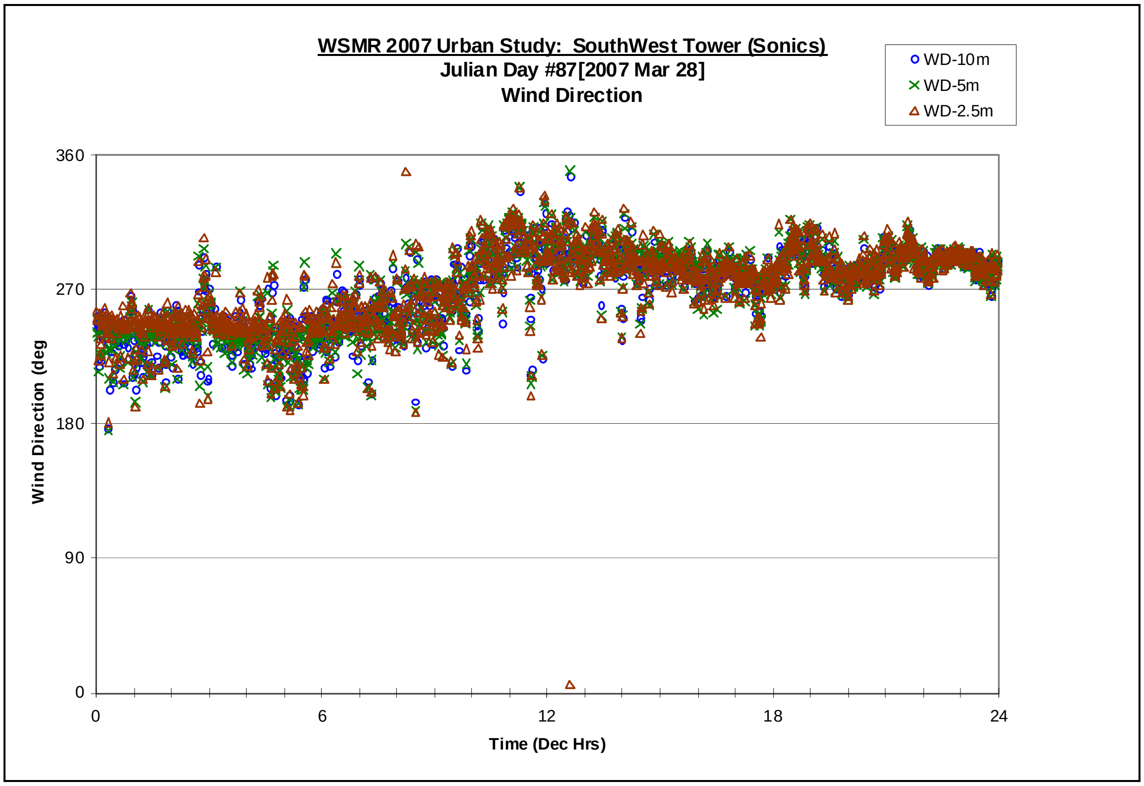

Figure E-10b. 2007 March 28, wind direction.

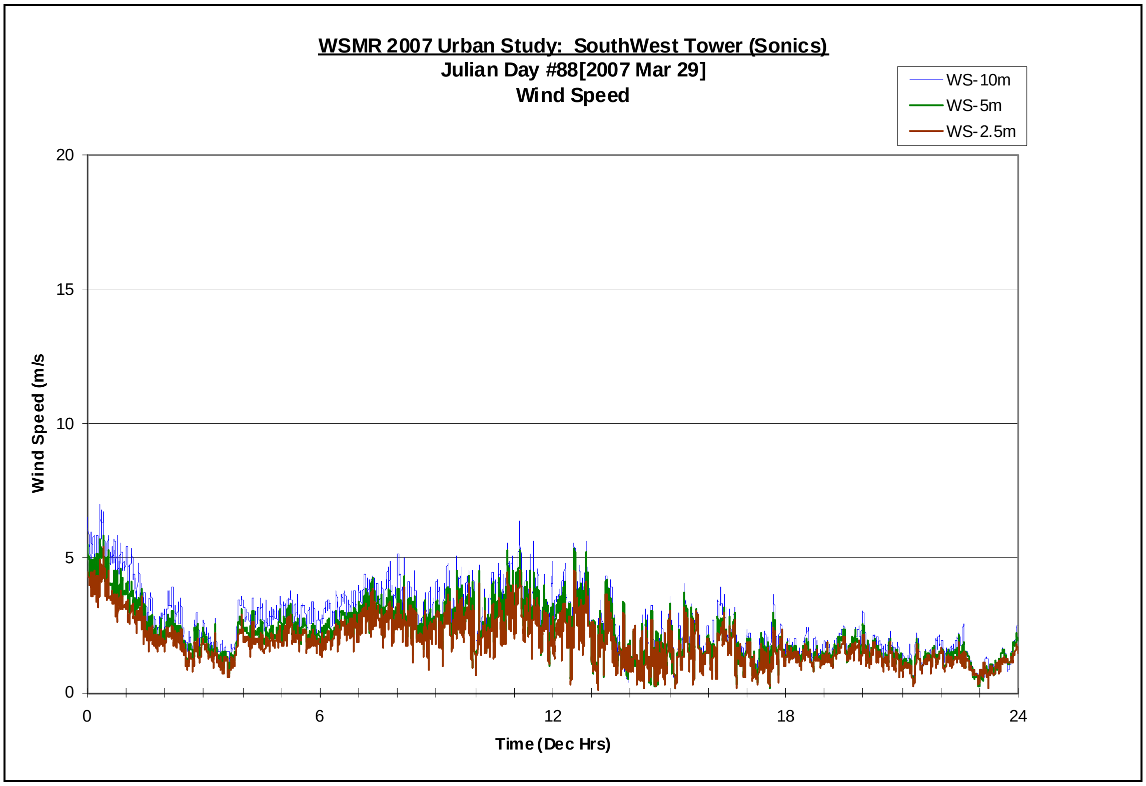

Figure E-11a. 2007 March 29, wind speed.

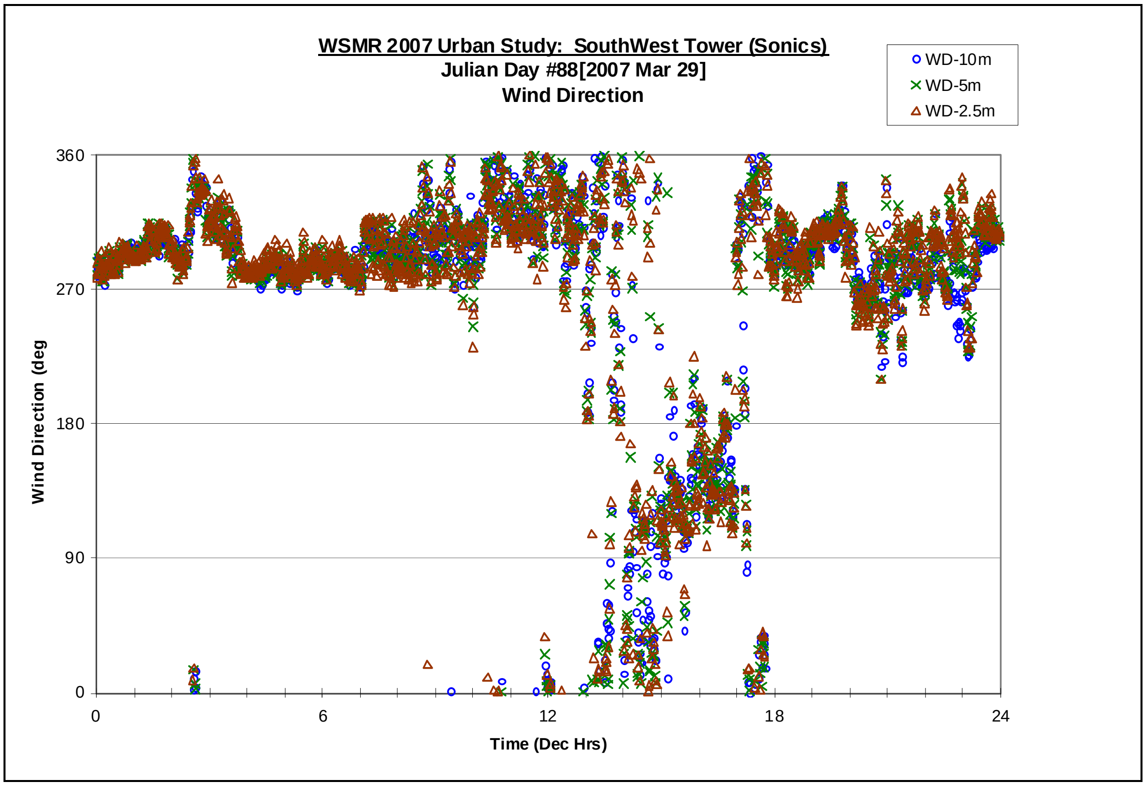

Figure E-11b. 2007 March 29 wind direction.

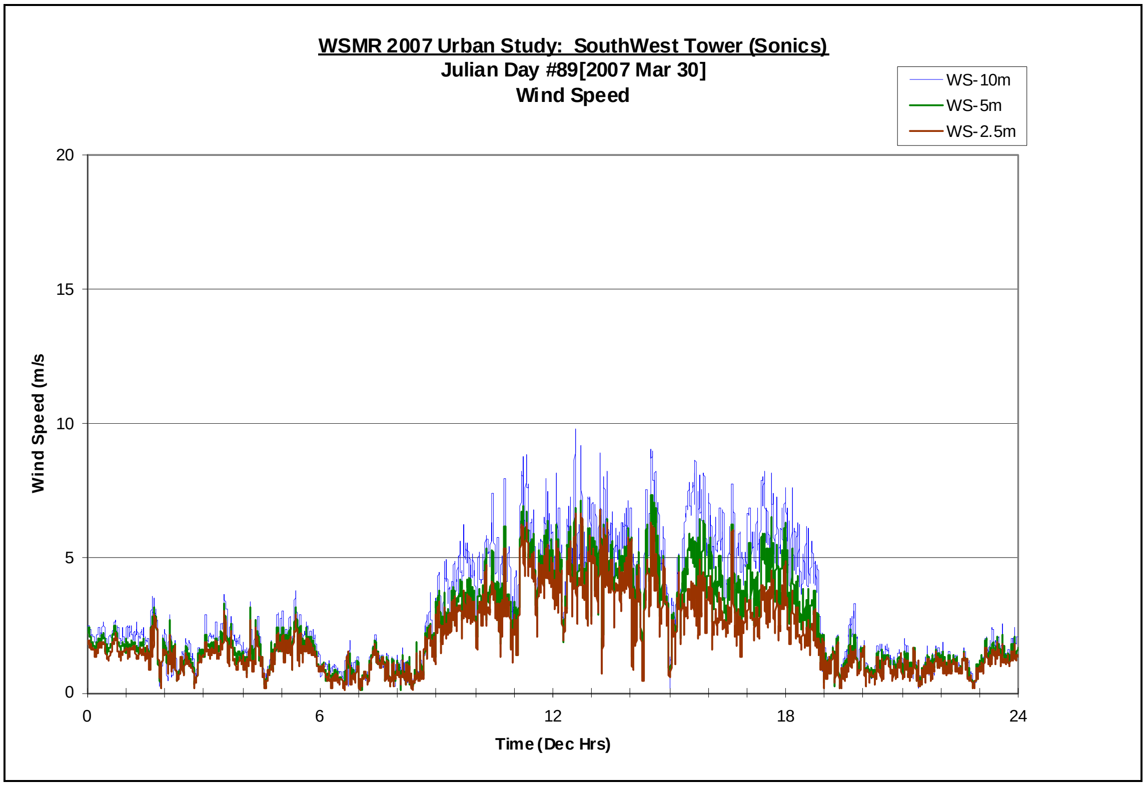

Figure E-12a. 2007 March 30, wind speed.

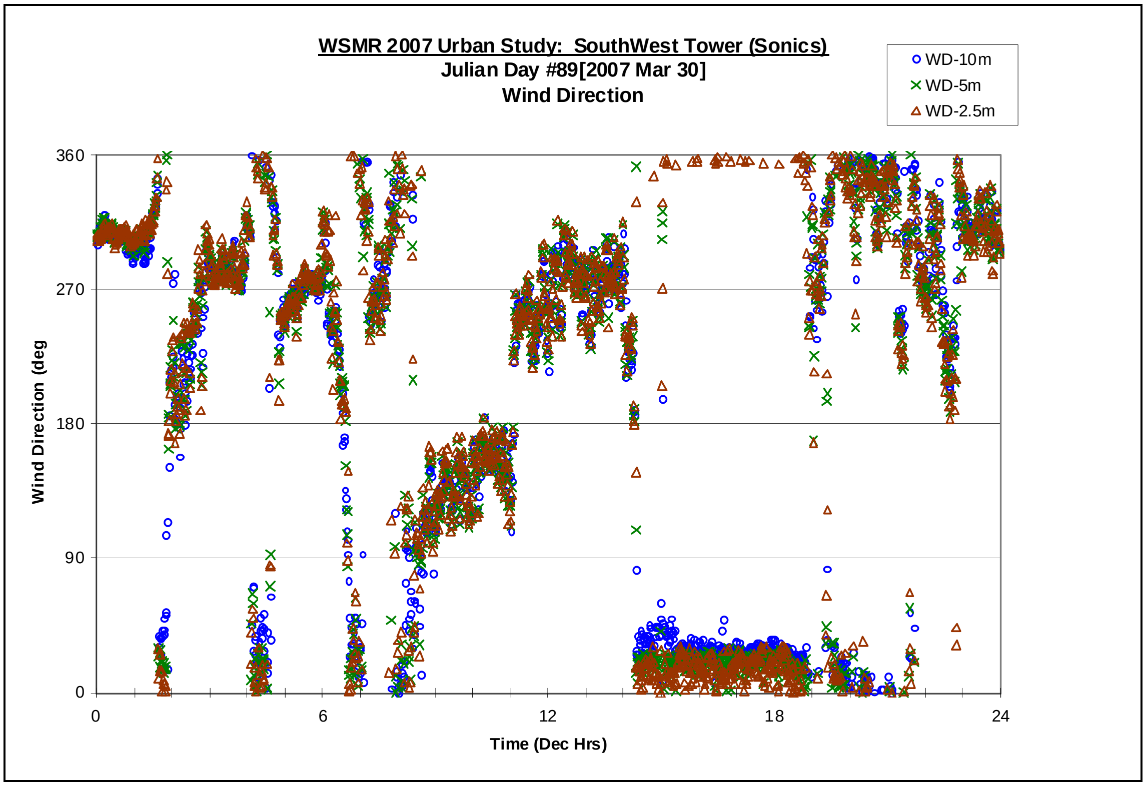

Figure E-12b. 2007 March 30, wind direction.

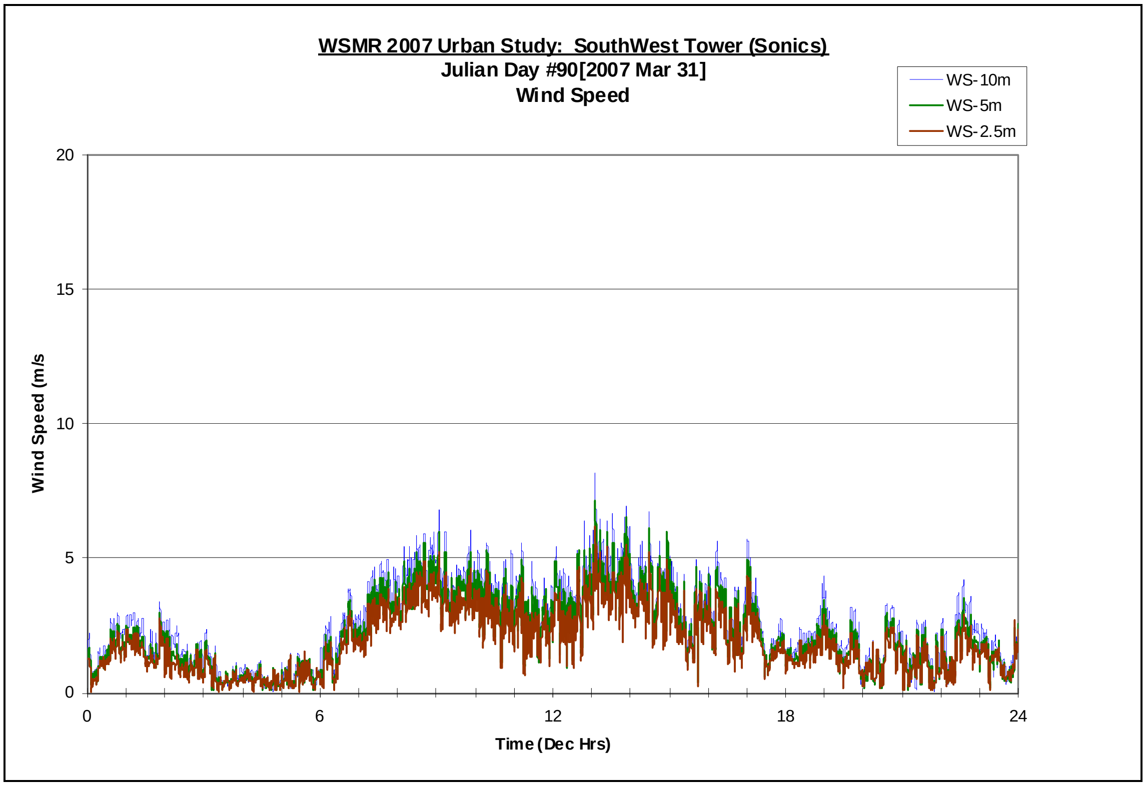

Figure E-13a. 2007 March 31, wind speed.

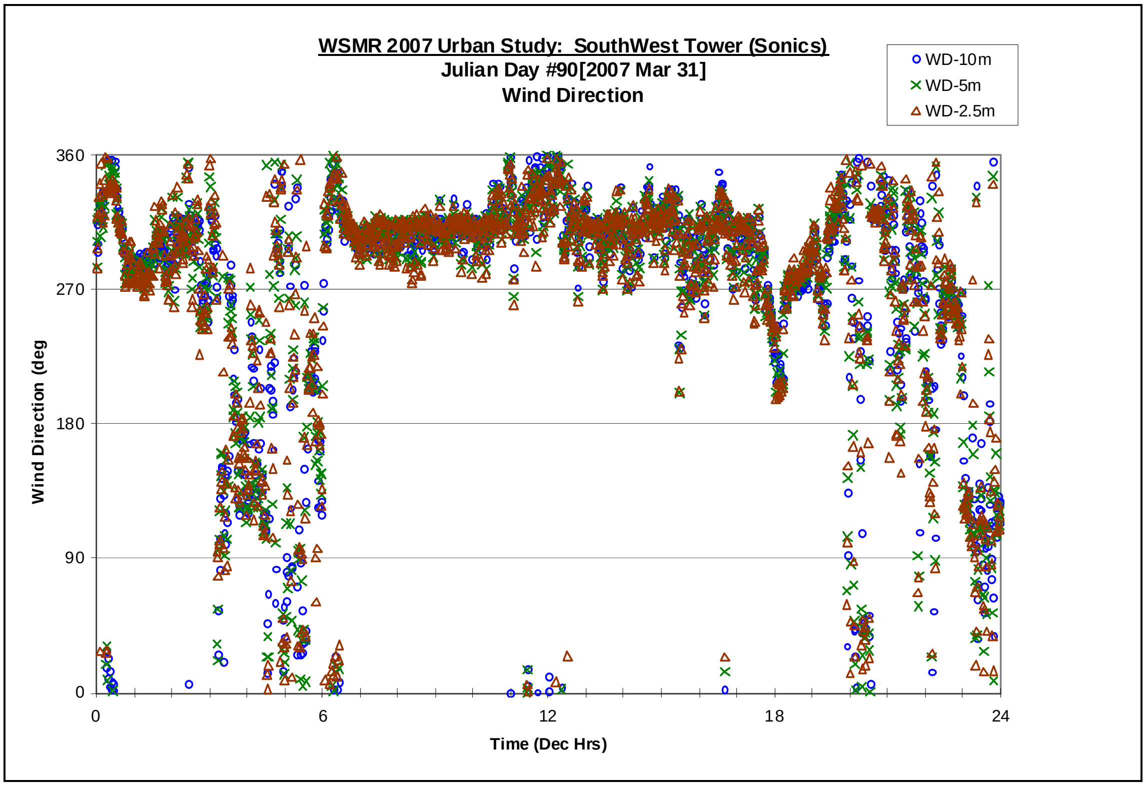

Figure E-13b. 2007 March 31, wind direction.

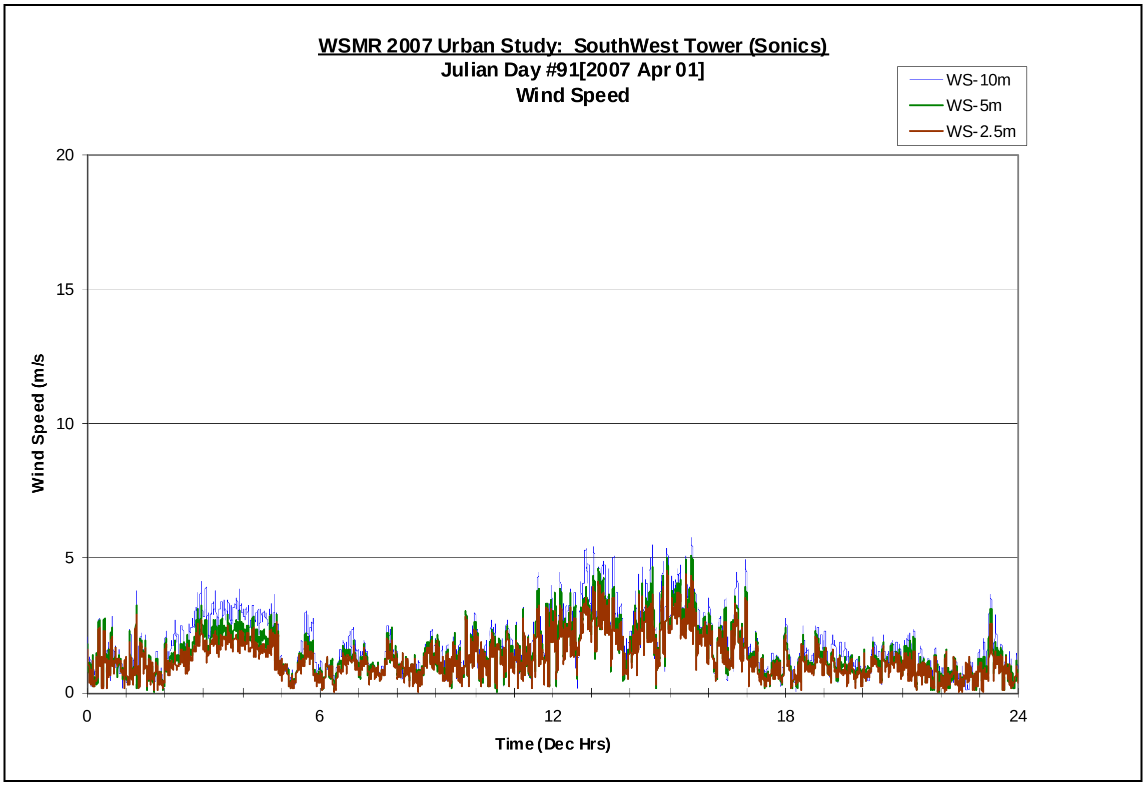

Figure E-14a. 2007 April 1, wind speed.

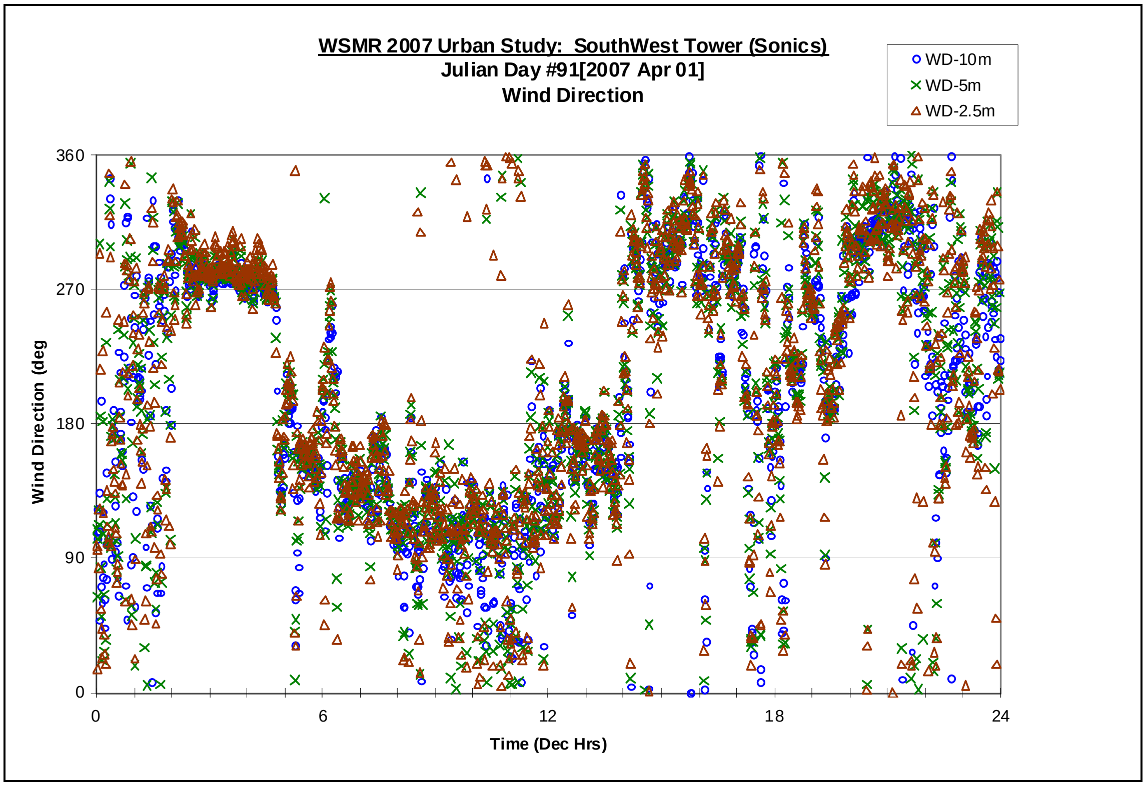

Figure E-14b. 2007 April 1, wind direction.

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Acronyms

3DWF	Three-Dimensional Wind Field (model)
AGL	above ground level
ARL	U.S. Army Research Laboratory
AS	atmospheric stability
DAS	data acquisition system
dec hr	decimal hours
DP	data processing
E	east
LT	Local Time
N	north
NE	northeast (tower)
NN	north (tower)
NTP	Network Time Protocol
NW	northwest (tripod)
RAZ	Reattachment Zone
RE	Reattachment Zone – east (tripod)
RN	Reattachment Zone – North (tripod)
RR	Roof (tripod)
RS	Reattachment Zone – South (tripod)
S	south
SE	southeast (tower)
SW	southwest (tower)
USB	universal serial bus
VAD	Velocity Acceleration and Velocity Deficit

VN	Vortex – north (tripod), a.k.a., Leeside Corner Eddy - North
VS	Vortex –south (tripod), a.k.a., Leeside Corner Eddy - South
W	west
WSMR	White Sands Missile Range
W03US	*White Sands Missile Range 2003 Urban Study*
W05US	*White Sands Missile Range 2005 Urban Study*
W07US	*White Sands Missile Range 2007 Urban Study*

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